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PROCEEDINGS OF THE SEVENTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH

Held at Manhattan, Kansas
November 3-5, 1971

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WHEAT UTILIZATION

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THE SEVENTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH was held in Manhattan, Kans., November 3-5, 1971. F. W. Smith, Director, Agricultural Experiment Station, Kansas State University, welcomed the attendants.

The objective of the wheat utilization research conferences is to provide a forum for all segments of the wheat industry to exchange ideas, problems, and answers, with the goal of creating additional opportunities to produce, handle, process, and merchandise wheat.

Sponsors of the Conference were Agricultural Research Service, U.S. Department of Agriculture; Great Plains Wheat, Inc., and affiliated State agencies; Kansas State University; Millers' National Federation; National Association of Wheat Growers; and Western Wheat Associates, USA, Inc., and affiliated State agencies. Chairman of the Program Committee was W. C. Schaefer, Assistant to Director, Northern Regional Research Laboratory, Agricultural Research Service, USDA, Peoria, Ill. Chairman of Local Arrangements was R. Carl Hoseney, Associate Professor, Department of Grain Science and Industry, Kansas State University.

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This report was prepared at the Northern Regional Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Peoria, Ill. 61604. Copies are available on request.

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PROCEEDINGS OF SEVENTH NATIONAL CONFERENCE ON WHEAT UTILIZATION RESEARCH
Held at Manhattan, Kansas, November 3-5, 1971

CEREALS AS A FUTURE SOURCE OF INDUSTRIAL ENERGY

By Dwight L. Miller, Northern Regional Research Laboratory, Agricultural Research Service, United States Department of Agriculture

Webster's Dictionary defines energy as "the equivalent of or the capacity for doing work." It also defines energy as "the capacity of acting, operating, or producing an effect." The first law of thermodynamics is also known as the law of conservation of energy. The essential idea is that energy may be changed in form, but it cannot be created or destroyed. In this discussion, an appraisal will be made of the U.S. industrial energy outlook and the possible contribution that agricultural cereal grains can offer.

Cereal grains and in fact most agricultural raw materials, with the possible exception of wood, have been little used or have received little attention as U.S. industrial energy sources. Yet, cereals provide directly or indirectly the major portion of approximately 1,000 trillion B.t.u. required per year by the population and at least an equal amount for domestic animals. The possibilities offered by wheat and other cereal grains in supplying the spiraling energy demands justify major considerations. Agricultural products represent renewable energy in contrast to such nonrenewable materials as oil, gas, and coal on which we have so long depended.

U.S. industry is now on the verge of losing one of its long standing basic worldwide advantages. It is fast running out of low-cost energy. Even as late as 2 years ago we were able to extract from our own reserves sufficient supplies of the low-cost energy fuels--oil, gas, coal, and uranium--to meet the needs of both commerce and the general public. Low cost, plentiful, and dependable raw materials have been basic to our national growth and prosperity. Energy fuels constitute about three-fourths of all the mineral raw materials consumed and are basic to our economy. To be specific, oil supplies the bulk of the energy that powers the machines which have lifted Western man above the level of a beast of burden. With high energy consumption goes a high standard of living. Man's muscle power is rated at only about 1/20 hp. continuously. On this basis it takes at least 2,000 men just to propel a small automobile. Each jet aircraft pilot controls the energy equivalent to about one million men.

There are many common and potential energy sources. To petroleum, gas, coal, and nuclear, we can add hydroelectric, geothermal, oil shale, tar sands, tidal, solar, agriculture, and many others. Some of these, such as solar, are tremendous in amounts, but present technology is not known for economically utilizing such energy sources. A field of corn or wheat utilizes only in the order of 1 or 2 percent of the available solar energy that hits it.

A B.t.u. is defined as the heat required to raise the temperature of 1 pound of water 1° F. Practically every energy source has its own form of common measure that is often confusing. The B.t.u. equivalent of some common fuels is tabulated in table 1 (3). As an order-of-magnitude, cereal grains and their byproducts have a heating value of about two-thirds that of bituminous coal, or in the order of 8,000 B.t.u. per pound.

TABLE 1.--B.t.u. equivalents of common fuels

Fuel	Common measure	B.t.u.[1]
Crude oil	Barrel, 42 gal.	5,800,000
Natural gas	Cubic foot	1,032
Coal	Ton	24 to 28,000,000
Electricity	Kilowatt hour	3,412

[1] Two trillion B.t.u. per year are approximately equal to 1,000 barrels per day of crude oil.

The United States energy balance for 1970 and as projected to 1985 is shown in figure 1. The 68 thousand trillion B.t.u. consumed in 1970 is predicted to increase by 84 percent to around 125 thousand trillion B.t.u. by 1985. An increase of 23 percent is predicted as soon as 1975 and 53 percent by 1980 (3).

The distribution of this energy consumption at the primary source is summarized in table 2 (3).

Electric utilities will have the largest growth rate and are predicted to increase their share of industrial energy from 25 percent of the total in 1970 to more than 35 percent by 1985. Electric energy produced in large and efficient power plants will replace many small and less efficient energy sources now used in residential and industrial locations.

Low-cost raw materials to meet these increasing demands are of major concern. In 1970, more than 75 percent of our oil came from domestic production. According to the 1985 predictions, only 42 percent will be domestic oil, even though its volume will be about the same. Last year our oil import bill was nearly $3 billion, and as early as 1975 this bill will probably be more than $8 billion. Most of this imported oil must come from one place, namely, the Near East. Thus, our dependency on this politically unstable area could result in that region having a significant voice in U.S. domestic and foreign policies. Europe already is primarily dependent on imported oil and may no longer control its own industrial energy resources.

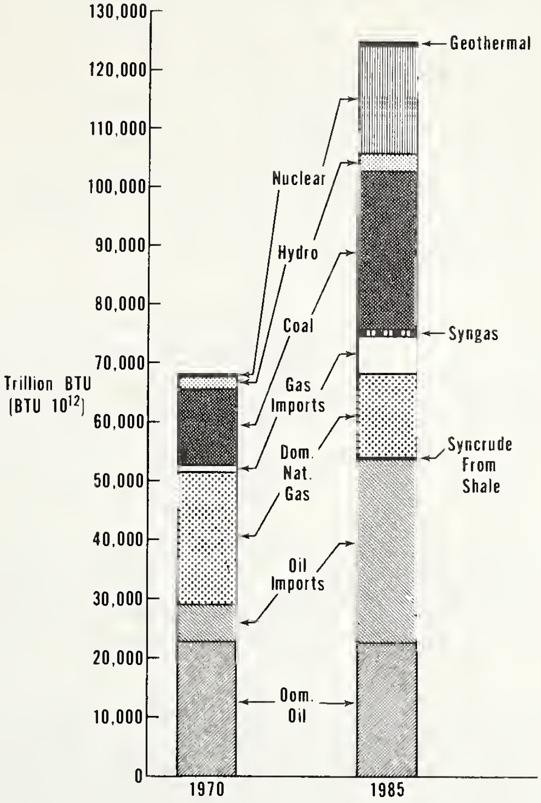

Figure 1.--U.S. energy balance.

TABLE 2.--Percentage shares of total U.S. primary energy consumption

Sector	Percentage of U.S. total 1970	1980	1985
Residential/commercial	19.2	16.2	15.0
Industrial	26.2	21.8	19.7
Transportation	24.0	23.3	22.6
Electric utilities	24.6	32.2	35.5
Nonenergy and miscellaneous	6.0	6.5	7.2
Total	100.0	100.0	100.0

We cannot replace our oil requirements with natural gas, which already provides about one-third of our current energy needs. Discoveries of new gas have been rapidly declining, and the U.S. proven reserves are now about 12 years, or slightly more than 13 years, if we include Alaska. A gas shortage is already here, and many major gas companies have announced that they will not accept new large commercial customers. There is some trend to convert coal, naphtha, and possibly petroleum into synthetic gas. Several announcements indicating this possibility have been made recently (1). However, the cost of synthetic gas will be much higher than present natural gas prices; some predictions are 400 to 500 percent higher. Even if large new discoveries of natural gas are made, future costs will be much higher than those for past discoveries.

Unlike oil or gas, coal reserves, which now provide about 20 percent of U.S. energy needs, do seem to be adequate for the predictable future. However, objections to air pollution, strip-mining, and general environmental considerations have made coal unpopular and many times unusable. Apparently we cannot use our coal and at the same time meet all environmental demands. Something has to give.

Nuclear power, rapidly entering this industrial energy picture (fig. 1), must go through extensive growth before it can provide the enormously increased demand for energy. Nuclear power is probably a partial solution to our energy problem for the remainder of this century.

Energy supply is not simply a question of energy reserves. It also takes time and large amounts of money. Roughly, it takes 7 years to construct and get a nuclear power plant into operation, 5 years to develop a coal mine, and at least 3 years to develop an oil field. One of the recently announced synthetic gas plants has a minimum start-up time requirement of 5 years and could be much longer. Costs for developing these facilities, of course, are mammoth. According to a recent evaluation, the capital requirements to meet just the 1985 U.S. energy demands will be in the order of $374 billion (table 3) (3). It does seem impossible that these expenditures will be met, but yet if they are not, we may well face extensive limitations on what can be done with the available energy supply.

As mentioned earlier, agricultural crops convert and store solar energy and this energy is renewable. Traditionally, the cost of stored energy from agricultural raw materials has been much higher than the energy from traditional mineral sources. Agriculture has provided the food, feed, and fiber for which a higher price could be paid. However, as indicated earlier, we may expect that the cost of energy from mineral fuels will increase and that supplies of oil and gas may no longer be available.

The ethics of using cereal grains for industrial energy instead of for food is a controversial subject and outside the scope of this discussion. If the U.S. produced cereal grains at maximum production, the 50 plus percent excess over its own normal requirements could undoubtedly be consumed throughout the world as food. However, most of these grains would have to be given away. How to do so without drastic effects on the U.S. economic system and the world economies remains to be resolved. Possibly, in some regions, the cereals could be bartered for such industrial energy fuels as oil. Many of the major oil-surplus nations could use more food.

TABLE 3.--Capital requirements for U.S. energy (1971-1985)

Item	Billion dollars
Oil and gas production	92
Oil refining[1]	20
Oil transportation (marine and pipelines)	18
Gas transportation	21
Coal production	9
Coal transportation	6
Nuclear production and processing	5
Oil from shale	0.5
Syngas plants	2.5
Subtotal	174
Electric power plants and transmission lines	200
Total	374

[1] Excludes foreign facilities

There are approximately 2,266 million total acres (4) in 50 States. The land in farms is about 1,110 million acres of which there are potentially about 630 million acres that could be cultivated. Currently, about 360 million acres are cultivated for crops. Increased cereal grain production yields per acre for the past decade have exceeded the population growth rate of the U.S. population. Chances are small that our present population will ever see famine conditions in the United States.

If we were to use approximately 100 million of these available uncultivated acres and grow on them the best yielding cereal grain (i.e., wheat, corn, sorghum) and if we assume an overall average yield of 70 bushels per acre (approximately 3,900 pounds), that grain could be converted into about 18 billion gallons of ethyl alcohol. This amount is 20 percent of the motor fuel that will be consumed in the Unites States this year, and it would be in a usable form. The effects of this production on agriculture and on our industrial energy supply would be significant (2).

The energy equivalent from an acre of wheat is calculated in table 4. If we assume that 30 bushels of grain was burned, it should yield about 12.5 million B.t.u. If the starch in the grain was converted to alcohol, that alcohol should contribute about 6.1 million B.t.u., and a byproduct feed would still be available. The straw from this acre if collected and converted to energy by burning would yield an additional 28.8 million B.t.u.

TABLE 4.--Wheat--production of industrial energy
(Basis: One acre - 30 bushels at 13.5% moisture)

Wheat	Million B.t.u.
Grain	
Whole grain - heat equivalent	12.5
Convert to alcohol[1] - heat equivalent	6.1
Straw	
Heat equivalent	28.8

[1] Plus 470 pounds of byproduct grain.

From an overall agricultural energy standpoint, the large amounts of straw, grasses, animal residues, and other agricultural materials that might become available are also significant. The weight of collectible residues from current U.S. agricultural production is more than 130 million tons annually. These amounts do not include animal residues and many other byproducts of agriculture. The heat equivalent of these residues would be more than 2,000 trillion B.t.u. based on a heating value of 8,000 B.t.u. per pound, or about 60 percent of that of bituminous coal. Unfortunately, the residues are located throughout all the 50 States and collection costs are relatively high.

We cannot afford to wait too long to pursue the necessary research to discover and develop the future energy sources and supplies. This country has needed and developed many new sources of energy as shown in figure 2. First, after wood, wind, and waterwheels, it was coal. Although coal started being used in 1780 or so, it was not until 1870, after development of several of the more modern energy consuming machines that coal became important.

Gas came next in 1816, but this too did not become important until many years later when, in 1930 or about, natural gas began being piped long distances to market.

Oil was discovered in 1859, but it did not become an important item of commerce until 1919 when the mass production of internal combustion engines began.

The next new source of energy was hydroelectric power in 1890, but this had to await the invention and development of electric power generators.

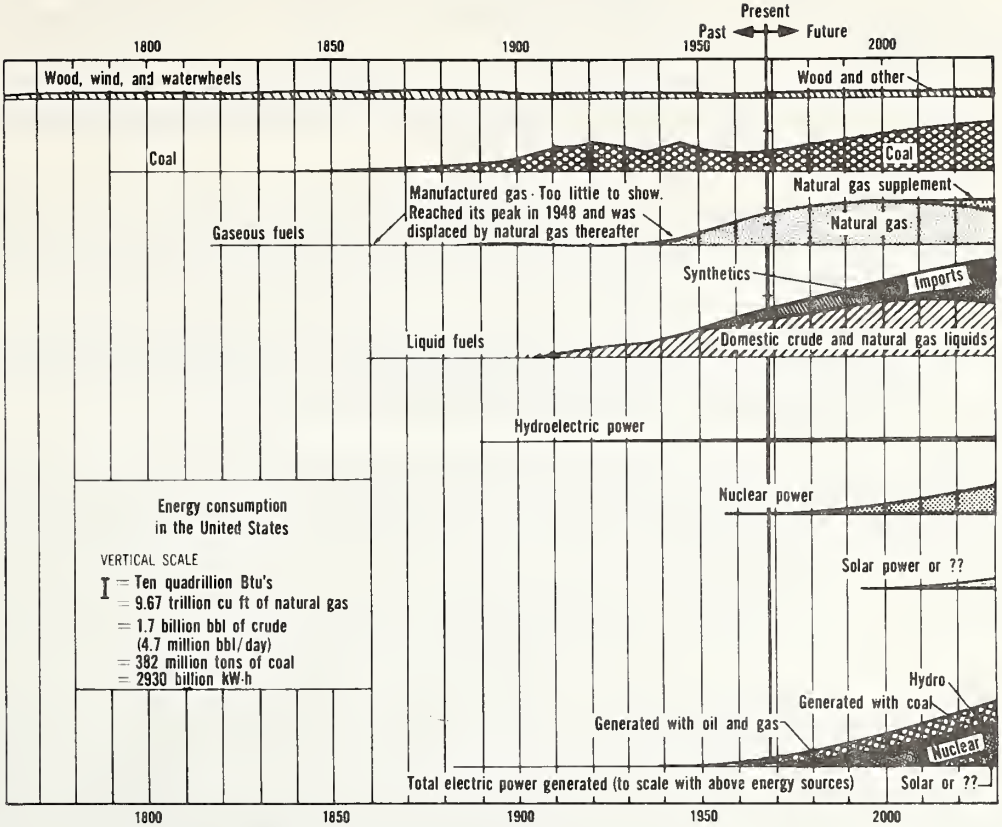

Figure 2.--Energy consumption in the United States chronologically.

Following that development, over half a century elapsed before another new source of energy was discovered--nuclear fission. This became commercial with the building of the first prototype plant in Shippingport, Pa., in 1957.

Now, if history continues to repeat itself, it is quite reasonable to expect that another new source of energy will begin to make itself felt before the year 2000. This could be new forms of nuclear power or some other source of energy that has not yet been discovered. It could be solar energy either by direct capture using such processes as solar cells, solar batteries, or absorption techniques or through photosynthesis processes such as growing crops. Agriculture depends on solar energy and could possibly have an important role in the future industrial energy supply. Major research programs directed towards that use should be initiated soon.

Summary

U.S. industrial energy requirements are increasing rapidly and will almost double in the next 15 years.

Proved reserves in traditional low-cost energy fuels are decreasing, and energy sources must be developed through imports, new discoveries, and alternate forms.

Industrial energy costs in the United States will undoubtedly increase gradually but significantly in the future.

U.S. agriculture has the potential to provide significant industrial energy from cereal grains and such byproducts as straws, stalks, hulls, and processing materials.

The possibility exists for producing and exchanging excess agricultural materials, particularly cereal grains for such energy raw materials as oil. The major oil-surplus nations are food-shortage nations.

Major research and economic programs should be initiated and carried out to determine the methods for, and economic feasibility of, utilizing wheat and other cereal grains for the production of industrial energy in the 50 States.

Literature Cited

(1) Anonymous. Natural Gas--The Next Process Industry Looms, Chem. Eng. News 49(35):8-9. August 30, 1971.

(2) Miller, Dwight L. Industrial Alcohol from Wheat. In Report of Sixth National Conference on Wheat Utilization Research, Oakland, Calif., November 5-7, 1969, U.S. Agricultural Research Service, ARS 74-54, pp. 20-33. August 1970.

(3) National Petroleum Council. U.S. Energy Outlook, An Initial Appraisal--1971-1985, An Interim Report, Vol. I, July 1971.

(4) U.S. Department of Agriculture, Agricultural Statistics 1970. U.S. Government Printing Office, Washington, D.C. 20402.

FUEL ALCOHOL FROM WHEAT

By Dwight L. Miller, Northern Regional Research Laboratory, Agricultural Research Service, United States Department of Agriculture

Introduction

At the Sixth National Wheat Utilization Research Conference held in Oakland, Calif., on November 5-7, 1969, I presented a paper on industrial alcohol from wheat (1). At that time I discussed the comparative economics of fermentation and synthetic ethyl alcohol; the potential effects on U.S. Agriculture if fermentation alcohol was required by law to be used in motor fuel; and some possible trends in the motor fuel industry.

Such a discussion was apparently long overdue. The paper has been reproduced in whole or in part by many scientific, trade, State, and academic publications. Visitors and inquiries have come from all over the United States and, in fact, the world. I appeared by invitation before a Senate Committee hearing on pollution, and the testimony was published in both the Federal Register and the Congressional Record (3). Requests for information continue at a steady rate from all sources.

The complete effects of this latest overall reevaluation of alcohol as a motor fuel cannot be accurately determined. However, major consideration of alcohol motor fuels is now evident in the United States, Canada, and other countries where excess supplies of cereal grains prevail. Passage of Legislative Bill 776 (2) by the Nebraska Legislature on May 26, 1971, is one of the most definitive actions. This law provides an allowance of $0.03 per gallon in the State motor fuel tax when fermentation ethyl alcohol is added to lead-free motor fuels. The Nebraska law also makes funds available for research on, and the promotion of, ethyl alcohol from cereal grains in motor fuels.

In today's discussion about fuel alcohol from wheat, I shall endeavor to bring the subject into perspective by relating changes that have occurred in the past 2 years and also by updating overall alcohol production and use economics. My previous report on future industrial energy requirements, continued excesses of U.S.-produced cereal grains, and recognized needs to improve our environment are evidence of the importance of power alcohol. Additional research is needed to take appropriate action and to make the correct decisions.

Wheat has primarily been used as a food grain, and except in times of national emergencies or unusual price situations, only a small fraction of total U.S. production has been consumed as feed and used for industrial purposes. The utilization of wheat in the United States for the past 35 years is plotted in figure 1. Industrial uses have been small and are now equivalent to about 15 million bushels annually. For many years the United States and several other countries have produced, or have been able to produce, much more wheat than they need or could profitably export. This situation will possibly continue on an average for the predictable future and new, high-yielding, hybrid varieties could greatly increase the already abundant supply.

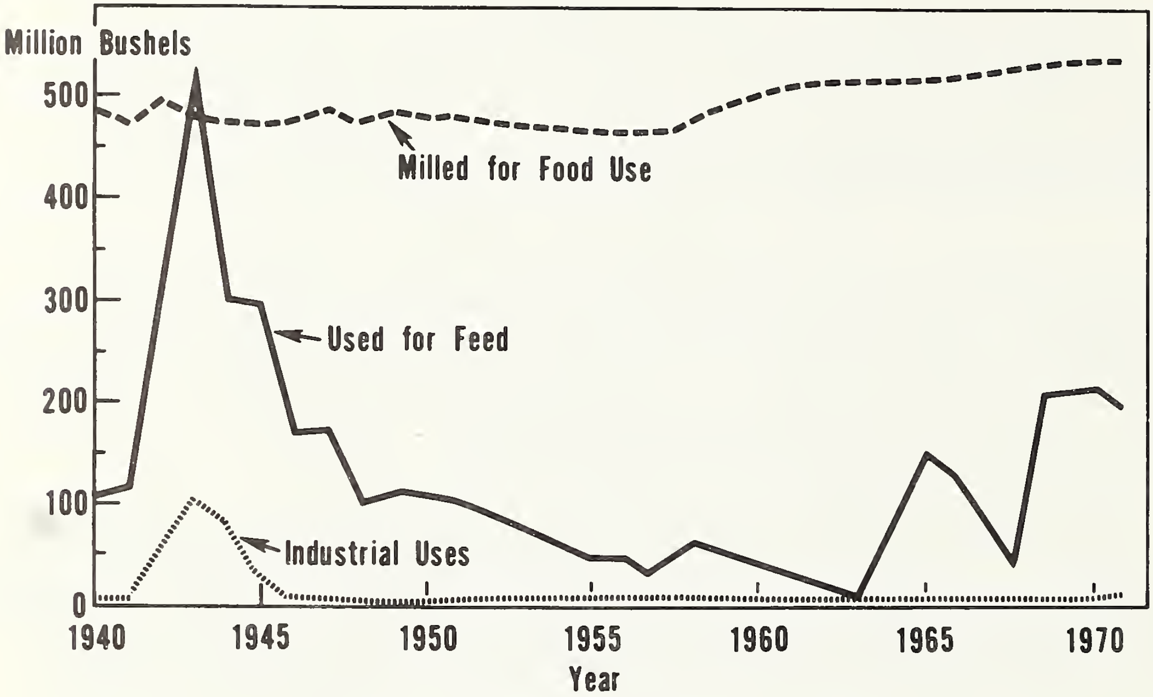

Figure 1.--Utilization of wheat in the United States.

The production and conversion of excess wheat and other cereal grains into usable motor fuels have been considered for a long time. The production of ethyl alcohol through fermentation has been investigated, and its motor fuel usage, though limited, has been practiced in several nations. However, volume usage for this purpose in the United States has not been practiced, primarily because it has not been economical to do so.

Since my presentation on "Industrial Alcohol from Wheat" (1) at the Sixth National Wheat Utilization Research Conference 2 years ago, major economic and sociological changes have developed in the United States. The possibility of lead removal from motor fuels was only being discussed then. Now, there is little question but that lead additives will be phased out completely, or greatly reduced in the 1970's. All new 1971 and later model cars made domestically have been designed to operate on lead-free gasoline, and such motor fuels are available at local service stations in most areas. The research octane number of this new leadless regular-grade gasoline is about 91 instead of the former 94. Perhaps the significant future value of lead-free gasoline, however, is not the elimination of lead from the exhaust, which has received practically all the publicity, but because it permits the use of efficient and long-life catalytic converters for exhaust pollution control. Ethyl alcohol could contribute octane value to these newer fuels, it should not poison the catalysts, and it would contribute a minimum of undesirable air pollution when burned. Consequently, today we have new fuel standards to consider.

The 1971 domestic consumption of automobile fuel will be about 90 billion gallons (4). If anhydrous ethyl alcohol were added at the minimum recommended blend of 10 percent (by volume), at least 9 billion gallons of alcohol would be required. Higher percentage alcohol additions would be suitable from a performance standpoint. Lower blend ratios or lower proof alcohol might also be, but they would require dual and more expensive fuel systems. However, the basic limitation on alcohol as a fuel is, and has been, unfavorable economics. Legislative action that would require by law to use ethyl alcohol blends (with the alcohol being produced from cereal grains; i.e., wheat) would be one way to secure a large volume market. Another way would be through major fuel tax allowances for alcohol blends. Such legislative action must also stipulate that the alcohol must be made from domestically produced grain to protect the American farmer.

Production

Commercial ethyl alcohol is practically all produced either by fermentation (fig. 2) or by chemical synthesis (fig. 3). Practically all fermentation ethyl alcohol now goes into the manufacture of beverages and pharmaceuticals. Ethyl alcohol needed industrially is produced synthetically from ethylene that comes from petroleum and natural gas sources. Synthetic alcohol has captured this industrial market because it costs less to produce than fermentation alcohol. The conversion cost of 190° and 200° proof ethyl alcohol from ethylene is summarized in table 1. The effect of ethylene cost on alcohol cost is shown in table 2. The future adequacy of the ethylene supply and possible cost trends are unresolved. At present there is more than enough available to produce more than 300 million gallons of industrial ethyl alcohol which are consumed annually. Ethylene cost is now about 3.5 cents per pound, f.o.b. production site.

Fermentation ethyl alcohol is made by the action of yeast on the starch and sugars present in natural raw materials. Cereal grains, including wheat, contain large amounts of starch. Alcohol production is directly related to the starch in the grain. The average composition of typical cereal grains is given in table 3. The theoretical yield of alcohol per pound of starch is 0.568 pounds. Yields in actual practice are about 90 percent of theoretical.

The cost of ethyl alcohol from wheat depends on many conditions, such as location, regional labor rates, and wheat variety. A representative estimate for conversion cost is made in table 4. The effect of wheat cost on ethyl alcohol cost is shown in table 5.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow 2\ C_6H_{12}O_6$$

Maltose Dextrose

$$C_6H_{12}O_6 \longrightarrow 2\ C_2H_5OH + 2\ CO_2$$

Dextrose Ethyl Alcohol Carbon Dioxide

Figure 2.--Conversion of starch and sugars into ethyl alcohol.

$$CH_2{=}CH_2 + H_2O \xrightarrow{\text{Catalyst}} C_2H_5OH$$

Ethylene Ethyl Alcohol

Figure 3.--Conversion of ethylene into ethyl alcohol.

TABLE 1.--Conversion cost of 190° and 200° proof ethyl alcohol from ethylene
(Exclusive of cost of ethylene)

Alcohol	Conversion cost
	Cents/gallon
190° Proof	
Base conversion cost	12.7
Depreciation ($2.9 million/year, 10 years, 50 million gallons)	5.8
Net	18.5
200° Proof	
1.048 gallons at 18.5 cents/gallon	19.4
Cost of dehydration	2.2
Total cost (exclusive of ethylene, profit, packaging, and sales expenses)	21.6

TABLE 2.--Effect of ethylene cost on ethyl alcohol cost

Alcohol	Ethylene, cents/pound 3.0	 4.0	 5.0
	Cost/gallon, cents		
190° Proof			
Ethylene	12.0	16.0	20.0
Conversion	18.5	18.5	18.5
Total manufacturing cost/gallon (exclusive of profit, packaging, and sales expenses)	30.5	34.5	38.5
200° Proof			
Ethylene	12.6	16.3	20.9
Conversion	21.6	21.6	21.6
Total manufacturing cost/gallon (exclusive of profit, packaging, and sales expenses)	34.2	37.9	42.5

TABLE 3.--Average composition of cereal grains[1]

Grain	Starch	Protein	Oil	Fiber	Other constituents[2]
	Percent	Percent	Percent	Percent	Percent
Hard wheat	64	14	2	2	18
Soft wheat	69	10	2	2	17
Dent corn	72	10	5	2	11
Sorghum	71	13	3	2	11

[1] Moisture-free basis.

[2] Minerals, sugars, pentosans, and vitamins.

TABLE 4.--Fermentative conversion cost of 190° and 200° proof ethyl alcohol from wheat
(Exclusive of cost of wheat)

Alcohol	Conversion cost
	Cents/gallon
190° Proof	
Base conversion cost	30.9
Depreciation ($1.4 million/year, 10 years, 17.2 million gallons)	8.1
	39.0
Byproduct feed credit (6 pound/gallon alcohol at $60/ton)	18.0
Net	21.0
200° Proof	
1.048 gallons at 21.0 cents/gallon	22.0
Cost of dehydration	2.2
Total cost (exclusive of wheat, profit packaging, and sales expenses)	24.2

TABLE 5.--Effect of wheat cost on ethyl alcohol cost
Basis: 2.6 gallons 200° proof alcohol/bushel

Wheat price/bushel dollars	Alcohol cost/gallon		
	Wheat	Conversion	Total[1] base cost
	Cents	Cents	Cents
1.00	38.5	24.2	62.7
1.25	48.0	24.2	72.2
1.50	57.7	24.2	81.9

[1] These costs do not include profits, packaging, and sales expenses.

If through legislative action, either by law or by adjustment of State taxes so that fermentation alcohol would be a required component of motor fuels, the effects on agriculture would be tremendous. It would take more than 3.4 billion bushels of cereal grains annually to produce 9.0 billion gallons of anhydrous alcohol for a 10-percent blend. This alcohol would cost more than $5.6 billion to produce from $1 per bushel grain. Approximately 525 fermentation plants with a total capital investment in the order of $7 billion would also have to be built. (Present total installed capacity is only 15 to 20 million bushels.) About 28 million tons per year of byproduct feed would be produced simultaneously.

The significant effects of this 28 million tons of byproduct feed on the market for other grains and cereals have not been evaluated. These high-protein byproduct feeds would not fill the gap left by the removal of a high proportion of feed grain from the market. These byproduct feeds would also compete with such materials as soybean meal, cottonseed meal, and other feed concentrates. Basically, there would be an excess of protein feed but not enough carbohydrate energy.

The production of lead-free motor fuel is at present one of the most active and controversial questions under study by the petroleum industry. Estimated additional overall costs of 0.2 to 7.0 cents per gallon and capital investments of $2 billion up to as high as $6 billion have been reported. The estimates from various sources are not in agreement. Most petroleum companies now charge an additional 3.0 cents per gallon for lead-free gasoline at the service station pump and to date such fuel has been marketed at a loss. There is also disagreement as to the effects of the additional petroleum refining and additives themselves on air pollution. Aromatic chemicals, which are extensively used to increase the octane number, are expensive and may promote air pollution. Many items remain to be resolved. However, there is little doubt that the removal of lead from motor fuels has caused, and will result in, more expensive fuels; will reduce the effective use of our domestic petroleum supplies; and will hasten our dependency on imported petroleum.

Opposition by the petroleum industry to the forced use of ethyl alcohol from grain in all motor fuel is probable. Wheat at $1 per bushel would add at least 5 cents per gallon to the present wholesale price of motor fuel containing tetraethyl lead. If the grain was provided free, a 10-percent blend would add at least one cent per gallon to the final price. Certainly the rapid elimination of lead from motor fuels will reduce the premium cost of alcohol over the present regular-grade fuels.

Summary

The production of ethyl alcohol from wheat and other cereal grains for motor fuel is technically feasible.

Lead probably will be removed, or greatly reduced, by law from gasoline motor fuels within 5 to 10 years. Removal in whole or in part is now in progress by all major suppliers. Alternate materials to improve octane rating and to reduce pollution must be found. Fermentation ethyl alcohol could fulfill this need, at least in part, but it is not now economically competitive with petroleum products.

Use of fermentation ethyl alcohol from domestic-produced wheat and other cereal grains as a required component of all motor fuels would require national legislative action. Such legislation and controls would have to specify the ratio of the types of cereal grains to protect different agricultural regions in the 50 States.

The phasing out of lead additives in motor fuels has reduced the cost premium for alcohol blends.

Cereal grain production in excess of U.S. requirements for food and feed (barring a national emergency or disaster) is possible for the predictable future. This renewable energy source could assist in meeting increasing motor fuel needs on the domestic market.

Major research and economic and marketing studies are needed to:

- Evaluate the effect of alcohol blends on performance and exhaust emissions in modern engines.

- Determine the feed value of byproducts from the production of ethyl alcohol from wheat and other cereal grains by fermentation.

- Evaluate the utilization and effects of 28 million tons of byproduct feeds.

Demonstrate in laboratory, pilot-plant and commercial-size operations the feasibility of alcohol-blend motor fuels in modern automobile engines.

Literature Cited

(1) Miller, Dwight L. Industrial Alcohol from Wheat. In Report of Sixth National Conference on Wheat Utilization Research, Oakland, Calif., November 5-7, 1969. U.S. Agricultural Research Service, ARS 74-54, pp. 20-33. August 1970.

(2) Nebraska Legislature. Legislative Bill 776. Legislature of Nebraska, Eighty-Second Legislature, 1st sess., passed May 26, 1971.

(3) U.S. Congress. House. Statement before joint meeting of Subcommittee on Air and Pollution, Senate Public Works Committee, and the Subcommittee on Energy, Natural Resources, and the Environment, Senate Commerce Committee. Alcohol-Gasoline Fuel Would Cut Pollution, Farm Surpluses. 91st Cong., 2d sess. Congressional Record 116(47): E2496-E2498, March 25, 1970.

(4) U.S. Bureau of Domestic Commerce. U.S. Industrial Outlook 1971. U.S. Government Printing Office, Washington, D.C. 20402. 495 pp.

Note: Because of the many requests for background information on this subject, the following bibliography is appended.

BIBLIOGRAPHY ON ALCOHOL PRODUCTION AND USE OF AGRICULTURAL CROPS AS A SOURCE OF MOTOR FUELS

Alcohol-Gasoline Blends

Mollier Diagrams for Theoretical Alcohol-Air and Octane-Water-Air Mixtures. R. Wiebe, J. F. Schultz, and J. C. Porter. Indus. and Engin. Chem. 34(5): 575-580. May 1942.

Iron Pentacarbonyl as Antiknock Agent in Alcohol Motor Fuels. I. Pitesky and R. Wiebe. Indus. and Engin. Chem. 37(6): 577-579. June 1945.

Solubility of Water in Alcohol-Hydrocarbon Mixtures. C. B. Kretschmer and R. Wiebe. Indus. and Engin. Chem. 37(11): 1130-1132. November 1945.

Octane Ratings of Agricultural Motor Fuels. C. F. Elder, F. R. Truby, and R. Wiebe. Indus. and Engin. Chem. 39(4): 508-510. April 1947.

The Technical Literature of Agricultural Motor Fuels. R. Wiebe and J. Nowakowska. U.S. Dept. Agr. Biblio. Bul. 10. February 1949.

Test Results with Dual-Fuel Carburetion at High Compression. J. C. Porter, A. P. McCloud, and R. Wiebe. Automotive Indus. 106(2): 46-50, 86. January 15, 1952.

Effect of Alcohols on Hydrocarbon Autoxidation. C. F. Frye, C. B. Kretschmer, and R. Wiebe. Indus. and Engin. Chem. 46(7): 1517-1520. July 1954.

Stability of Alcohol-Gasoline Blends (Estabilidad de las Mezclas Alcohol-Gasolina). J. Nowakowska, C. B. Kretschmer, and R. Wiebe. Bol. de la Asoc. Nac. de Ingen. Agron. 3(70): 3-7. February 1956. (English translation available)

Carburetor De-Icing with Alcohols (L'Alcool et le Dégivrage des Carburateurs). C. B. Kretschmer, M. M. Gilbert, W. B. Roth, and R. Wiebe. Indus. Agr. et Aliment. 73(5): 343-346. May 1956. (English translation available)

Road and Laboratory Tests of Vapor Lock in Alcohol Motor Fuels. C. B. Kretschmer, C. W. Blessin, M. M. Gilbert, W. B. Roth, and R. Wiebe. Philippine Agr. Engin. Jour. 6(1): 7-12. 1957.

Exhaust Gas Composition and Engine Wear. C. W. Blessin, C. F. Elder, W. B. Roth, and R. Wiebe. Philippine Agr. Engin. Jour. 6(2): 49-56. 1957.

High Compression Tractor Engines with Alcohol-Gasoline Blends. M. M. Gilbert, W. B. Roth, and R. Wiebe. Philippine Agr. Engin. Jour. 90(2): 239-248. 1961.

Volatility of Alcohol Motor Fuels. R. Wiebe, C. B. Kretschmer, and A. P. McCloud. Philippine Jour. Science 90(2): 223-238. 1956.

General Review Articles Dealing with Production, Use, and Economics of Alcohol

War Alcohol Obtained from Wheat through Coordinated Research. U. S. Dept. Agr. Res. Achievement Sheet 93(C). July 1948.

Industrial Alcohol. P. B. Jacobs. U. S. Dept. Agr. Misc. Pub. 695. February 1950.

Alcohol from Agricultural Sources as a Potential Motor Fuel. G. E. Hilbert. U. S. Dept. Agr. AIC-233 (Rev.). February 1950.

Production of Alcohol

Grain Alcohol Fermentations. Submerged Mold Amylase as a Saccharifying Agent. E. H. LeMense, V. E. Sohns, J. Corman, R. H. Blom, J. M. VanLanen, and A. F. Langlykke. Indus. and Engin. Chem. 41(1): 100-103. January 1949.

The Use of Fungal Amylase in the Industrial Production of Alcohol and Alcohol Products. R. W. Jackson, R. H. Blom, and H. M. Tsuchiya. Report on Recent Advances in the Fermentation Industries, published by the Royal Institute of Chemistry (Scotland). pp. 93-107. July 1950.

Methods and Costs of Producing Alcohol from Grain by the Fungal Amylase Process on a Commercial Scale. U. S. Dept. Agr. Tech. Bull. 1024. August 1950.

Utilization of Fungal Amylase for Alcohol Production. J. Corman and H. M. Tsuchiya. Cereal Chem. 28(4): 280-288. July 1951.

Mold Cuts Production Costs for Grain Alcohol. U. S. Dept. Agr. Res. Achievement Sheet 146(C). July 1951.

Plant Scale Evaluation of a Fungal Amylase Process for Grain Alcohol. A. M. Hanson, T. A. Bailey, R. C. Malzahn, and J. Corman. Jour. Agr. and Food Chem. 3(10): 866-872. October 1955.

Physical Properties of Alcohol in Connection with Its Use as a Motor Fuel

Solubility of Oxygen and Nitrogen in Organic Solvents from -25° to 50° C. C. B. Kretschmer, J. Nowakowska, and R. Wiebe. Indus. and Engin. Chem. 38(5): 506-509. May 1946.

Densities and Liquid-Vapor Equilibria of the System Ethanol-Isoöctane (2,2,4-Trimethylpentane) between 0 and 50°. C. B. Kretschmer, J. Nowakowska, and R. Wiebe. Jour. Amer. Chem. Soc. 70(5): 1785-1790. May 1948.

Liquid-Vapor Equilibrium of Ethanol-Toluene Solutions. C. B. Kretschmer and R. Wiebe. Jour. Amer. Chem. Soc. 71(5): 1793-1797. May 1949.

Liquid-Vapor Equilibrium of Ethanol-Methylcyclohexane Solutions. C. B. Kretschmer and R. Wiebe. Jour. Amer. Chem. Soc. 71(9): 3176-3179. September 1949.

The Solubility of Propane and the Butanes in Ethanol. C. B. Kretschmer and R. Wiebe. Jour. Amer. Chem. Soc. 73(8): 3778-3781. August 1951.

The Thermal Expansion of Water and 1-Propanol. C. B. Kretschmer. Jour. Phys. and Colloid Chem. 55(8): 1351-1355. November 1951.

Solubility of Gaseous Paraffins in Methanol and Isopropyl Alcohol. C. B. Kretschmer and R. Wiebe. Jour. Amer. Chem. Soc. 74(5): 1276-1277. March 5, 1952.

Pressure-Volume-Temperature Relationships of Alcohol Vapors. C. B. Kretschmer and R. Wiebe. Jour. Amer. Chem. Soc. 76(9): 2579-2583. May 5, 1954.

Thermodynamics of Alcohol-Hydrocarbon Mixtures. C. B. Kretschmer and R. Wiebe. Jour. Chem. Phys. 22(10): 1697-1701. October 1954.

Ethyl Alcohol-Water with 2,2,4-Trimethylpentane and with 1-Octane at 0° and 25° C. J. Nowakowska, C. B. Kretschmer, and R. Wiebe. Chem. and Engin. Data Series 1(1): 42-45. 1956.

Producer Gas from Agricultural Residues

Thermodynamics of Producer Gas Combustion. Application to Internal Combustion Engines. A. P. Oleson and R. Wiebe. Indus. and Engin. Chem. 37(7): 653-660. July 1945.

Bibliography on Construction, Design, Economics, Performance, and Theory of Portable and Small Stationary Gas Producers. J. Nowakowska and R. Wiebe. U. S. Dept. Agr. AIC-103. October 15, 1945.

Gasification of Agricultural Residues. J. C. Porter and R. Wiebe. U. S. Dept. Agr. AIC-174. March 1948.

Alcohol-Water Injection

Boosting Engine Performance with Alcohol-Water Injection. J. C. Porter, W. B. Roth, and R. Wiebe. Automotive Indus. 98(8): 34-37, 60. May 1, 1948.

Alcohol-Water Injection for Spark-Ignition Engines. R. Wiebe and J. C. Porter. U. S. Dept. Agr. AIC-240. July 1949.

Alcohol-Water Injection for High Compression Tractor and Automobile Engines. J. C. Porter, M. M. Gilbert, H. A. Lykins, and R. Wiebe. Agr. Engin. 31(2): 71-75. February 1950.

Dual Carburetion with Alcohol-Water Mixtures and Alcohol Blends (La Double Carburation par les Mélanges d'Alcool et d'Eau Utilisés comme Anti-Détonants d'Appoint ou par l'Emploi d'Essences Alcoolisées). R. Wiebe. Indus. Agr. et Aliment. 69(3): 203-208. March 1952. (English translation available)

Alcohol as an Antiknock Agent in Automotive Engines. J. C. Porter and R. Wiebe. Indus. and Engin. Chem. 44(5): 1098-1104. May 1952.

Alcohol-Water Injection for Farm Tractors. J. D. Hummell and R. Wiebe. U. S. Dept. Agr. AIC-349. February 1953.

Practical Experiences with Alcohol-Water Injection in Trucks and Farm Tractors. R. Wiebe and J. D. Hummell. Agr. Engin. 35(5): 319-326. May 1954.

Principles and Practice of Alcohol-Water Injection (Die Alkohol/Wasser-Einspritzung in Ottomotoren). R. Wiebe. Erdöl and Kohle 7(10): 643-647. October 1954. (English translation available)

Effects of Rotation and Alcohol-Water Injection on Farm Tractor Valve Life. J. A. Weber. Presented at Society of Automotive Engineers Golden Anniversary Tractor Meeting, Milwaukee, Wisconsin. September 12-15, 1955.

Use of Wheat in War Alcohol Program

The Production of Ethyl Alcohol from Wheat. Report of Conferences and Collaborative Work Undertaken by Industrial, University, and Federal Research Organizations for and with the Assistance of the War Production Board. Summarized by Northern Regional Research Laboratory. March 1944.

Alcohol Fuels from Cereals

Alcohols and Hydrocarbons as Motor Fuels. Jay A. Bolt, E. S. Starkman, H. K. Newhall, R. D. Sutton, George C. Lawrason, Pearle F. Finigan and Marvin W. Jackson. Society of Automotive Engineers, Inc., New York, N. Y. 10017. pp. 1-49. June 1964.

Industrial Alcohol from Wheat. Dwight L. Miller. Presented at the Sixth National Wheat Utilization Research Conference, Okaland, California, November 5-7, 1969.

Ethanol from Renewable Resources and Its Application in Automotive Fuels. A Feasibility Study. Report of a Committee Appointed by the Hon. Otto E. Lang, Minister Responsible for the Canadian Wheat Board. D. S. Clark, D. B. Fowler, R. B. Whyte and J. K. Wiens. Published by the Office of the Minister Responsible for the Canadian Wheat Board, House of Commons, Ottawa, Canada. pp. 1-118. January 1971.

CEREAL STARCH AND FLOUR PRODUCTS IN RUBBER AND PAPER

By C. R. Russell, Northern Regional Research Laboratory, Agricultural Research Service, United States Department of Agriculture

Progress toward the development of cereal starch and flour products for use in paper and rubber was reviewed by the author at the sixth session of this conference in 1969 (12). Significant advances in both of these areas of research during the past 2 years are presented here along with essential background.

Cereal Products in Rubber

Background

Current annual usage in the United States of reinforcing agents for rubber is about 6 billion pounds. This market is about evenly divided between black (carbon blacks) and nonblack reinforcing agents comprised mainly of clays, silicates, and silicas. Reinforcing agents are needed to give rubber sufficient tensile strength, stiffness, abrasion resistance, and other physical properties to meet end-use requirements. For effective reinforcement, particle size of the reinforcing agent must be in the submicron range. Cereal starches and flours function like conventional reinforcing agents if properly incorporated into rubber. The particle size of starch in either granule form or as a pregelatinized powder is much too large to be effective. However, if starch is solubilized and then insolubilized by crosslinking in the presence of latex (an aqueous suspension of colloidal rubber particles) sufficiently fine starch particles are formed to give very good reinforcement. The reactions (2,10) for solubilizing starch and then insolubilizing it in the presence of latex are shown in figure 1. Starch is treated first in an aqueous slurry with sodium hydroxide then with a small amount of carbon disulfide to give the soluble starch xanthate. The xanthate solution is then added to latex and the starch is insolubilized by crosslinking it through the xanthate groups with either zinc sulfate or nitrous acid. Addition of small amounts of resorcinol and formaldehyde to the xanthate-latex mixture before treatment with either zinc sulfate or nitrous acid enhances strength properties of the vulcanized or cured rubber but also imparts a dark mahogany color to it. The procedure for incorporating zinc starch xanthate in rubber is outlined in figure 2. As mentioned in connection with figure 1, the xanthate solution and latex are mixed thoroughly; then antioxidant is added, followed by zinc sulfate and sulfuric acid to effect crosslinking and to reduce the pH to about 6.5. The zinc starch xanthate and latex coprecipitate as large curds that are filtered (dewatered) on a wire screen. The dewatered curds are dried either in a force-draft oven or in a heated extruder. The dried material is then consolidated and mixed with additional antioxidant on a conventional roll mill to give what is called a masterbatch. Vulcanized rubber is made from the masterbatch in the usual manner by mixing in standard curing agents with heavy-duty mixers or roll mills and then curing in appropriate molds with heat and pressure. The same sequence is followed when other crosslinking agents (fig. 1) are

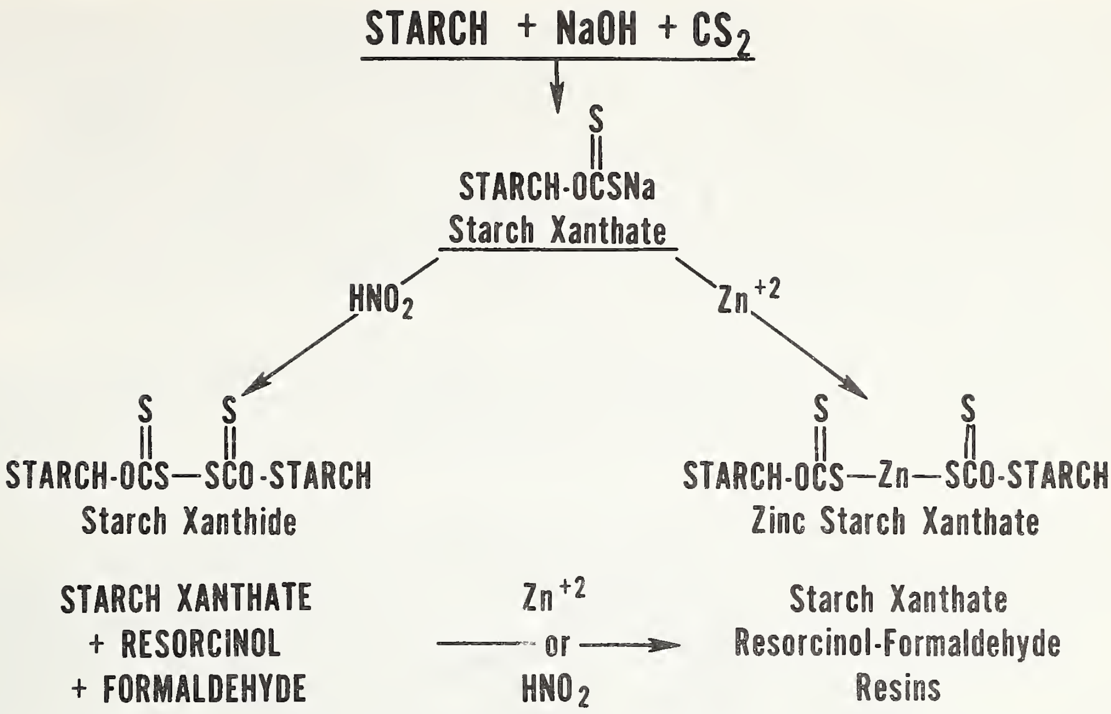

Figure 1.--Preparation of starch xanthate and its conversion to insoluble crosslinked products.

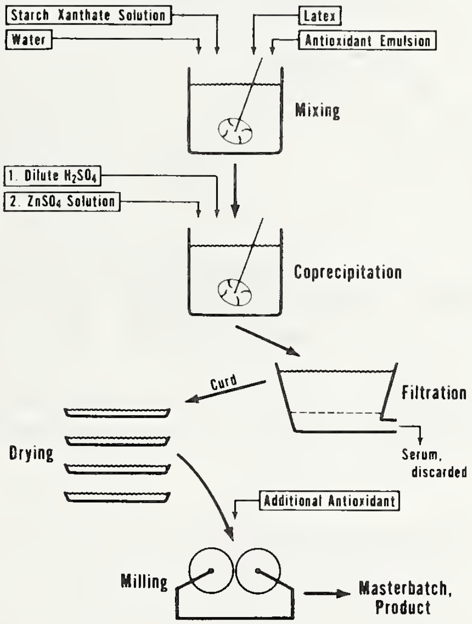

Figure 2.--Flow diagram of method of incorporating zinc starch xanthate in rubber.

used. The zinc starch xanthate and the xanthide (produced by crosslinking with nitrous acid) give light straw-colored semitransparent rubber, which can be converted readily to white rubber with the addition of much less of the costly zinc and titanium oxides than is needed in rubber reinforced with clays. In addition, these two starch products give stronger rubber than can be achieved by using common clays. To meet strength properties of the starch-reinforced rubber, comparatively costly pyrogenic silicas or treated clays are needed. The two starch-based reinforcing agents also have another advantage; they can be treated with dyes to give semitransparent brightly colored rubbers.

The tensile strength and ultimate elongation at break of styrene-butadiene rubber (SBR) reinforced with increasing amounts of starch xanthide and fine thermal (FT) carbon black are depicted in figure 3. The conventional way of expressing the amount of reinforcing agent or other additive in rubber compositions is as parts by weight of additive per 100 parts by weight of pure rubber ingredient and is abbreviated phr. Maximum tensile strength and elongation for xanthide-reinforced rubber that was extrusion-dried and rubber reinforced with commercial FT carbon black occur at about 50 phr loading with the xanthide-reinforced rubber being slightly stronger but a

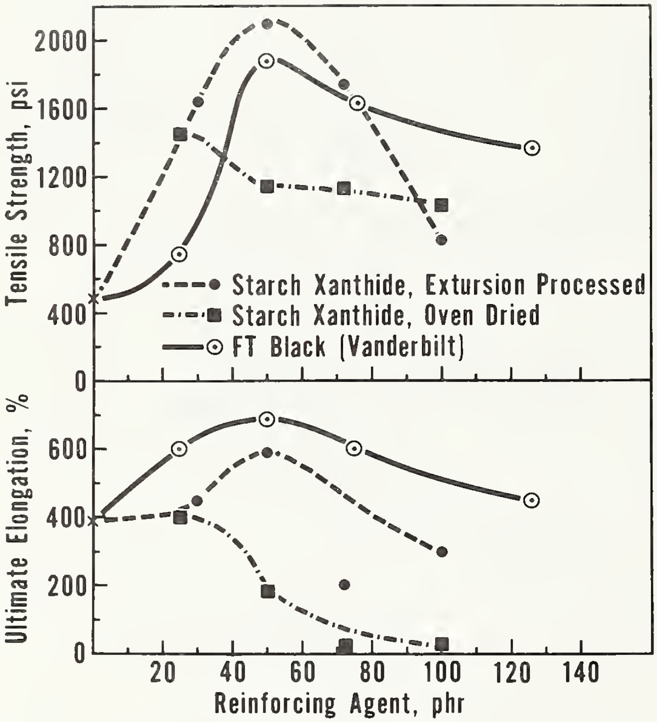

Figure 3.--Starch xanthide compared with carbon black as reinforcing agent in sytrene-butadiene rubber.

little less stretchy than the rubber reinforced with FT carbon black. While the oven-dried xanthide-reinforced rubber is weaker and less stretchy than the other rubbers, it is still strong enough and rubbery enough for many uses.

In studies (11) conducted for us under contract at the Institute of Polymer Science, Akron University, it was determined that starch-reinforced rubbers have best commercial opportunities as general-purpose molding compounds, oil-resistant rubbers, and shoe sole rubbers. Our rubber also appears to have potential as nontread rubber components in tires.

Previously we reported (12) that hard and soft wheat flour and corn flour could be substituted for starch in our process with no significant change in properties of the rubber.

Progress

For the past 2 years extensive work under one of our contracts has been carried out by the B. F. Goodrich Company on scale-up of our process and evaluation of starch-reinforced rubber. Some processing problems were encountered but were overcome without introducing any innovations incompatible with current practice in the industry. Thousand-pound lots of selected rubbers are now being made for exhaustive laboratory and in-service testing.

A major breakthrough, the development of low-cost powdered rubber (a much sought industrial goal) has been made by scientists in our Laboratory (1). They discovered that the oven-dried rubber curds (fig. 1) could be pulverized without sticking in an ordinary hammer mill. Like powdered or pelletized plastics, the powdered rubber can be injection molded or extruded without prior high-shear milling to give good-quality finished products. Curing agents and other desired additives are readily blended into the powder with light-duty ribbon mixers. Industry estimates that use of powdered rubber would reduce processing costs by at least 2-1/2 cents per pound of finished rubber goods by eliminating much of the heavy-duty equipment and power needed to incorporate curing and reinforcing agents, fillers, and other additives into conventional slab rubber. Without the addition of our starch products powdered rubber cannot be made except by costly means, such as grinding in the frozen state. In figure 4, left foreground, a pile of starch-filled powdered rubber is shown with a number of rubber articles that most likely could be made from the powder. The picture is actually illustrated with finished industrial products made from slab rubber like the large chunk shown in the right background because we are not equipped to make large enough articles from powdered rubber to show up effectively. Neither did we have time to make the necessary arrangements with industry. However, we have made smaller articles such as hoses and rods from the powder rubber without difficulty, and industrial firms who are experimenting with our powder say that it can be handled in conventional extruders.

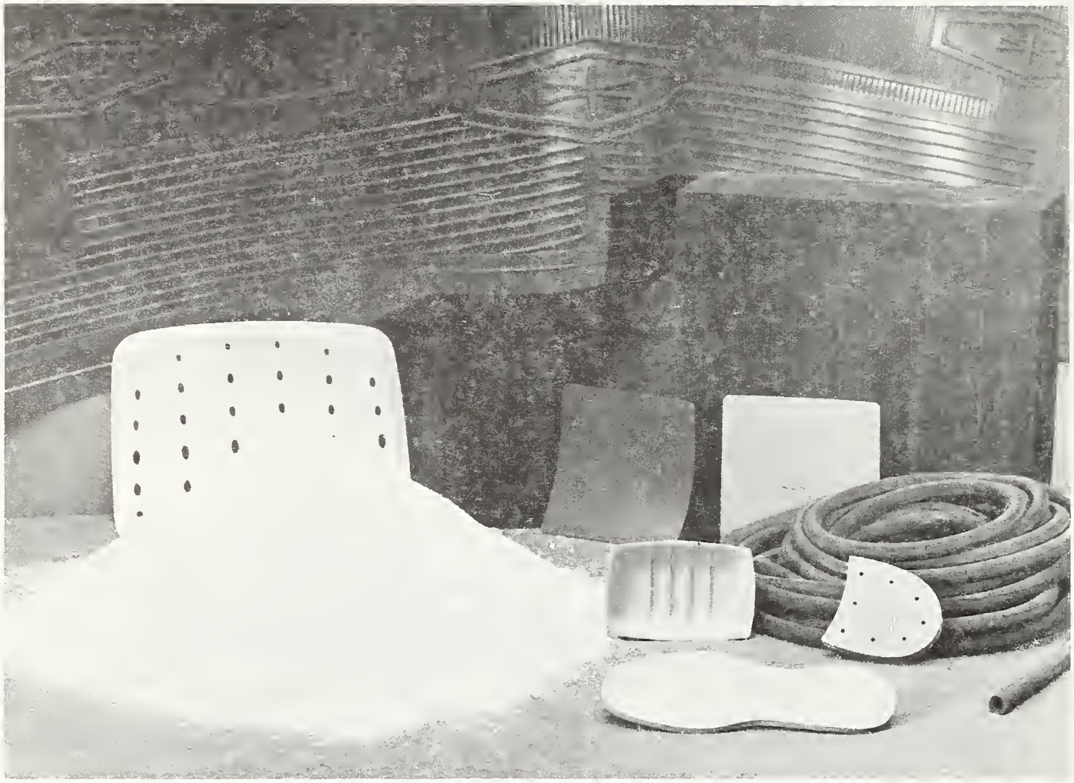

Figure 4.--Illustration of some potential uses for starch-filled powdered rubber.

No more than 30 phr starch product may be present in the initial powder without detracting from properties of the finished products. While properties of rubber goods made from our powder may be improved by blending in carbon black or nonblack reinforcing agents, addition of more starch reduces tensile strength, elasticity, and other desirable properties. Starch-filled powdered rubber has created widespread industrial interest because it alone gives strong enough rubber for many purposes, and it is readily modified by addition of other reinforcing agents to meet requirements for many end uses.

Work in our Laboratory has shown that crosslinked creal flour xanthates may be substituted for crosslinked starch xanthate in powdered rubber without detriment to its properties. In table 1, physical properties of test specimens made from powdered rubber containing 30 phr of crosslinked flour and starch xanthates are shown. Except for the rubber containing hard wheat flour, which is down a bit in tensile and elongation, the rubbers containing soft wheat flour and corn flour are equivalent for all practical purposes to the rubber containing starch.

Table 1.--Comparative vulcanizate properties of flour resin-SBR 1502

(Powder rubber masterbatches[1])

Vulcanizate	Hardness Shore A	Tensile	Elongation
		P.s.i.	Percent
Corn flour xanthate[2]	74	2,180	480
Soft wheat flour xanthate	76	2,040	415
Hard wheat flour xanthate	77	1,830	350
Pearl corn starch xanthate	78	2,200	400

[1] Each masterbatch contained 30 phr resorcinol-formaldehyde treated cereal product.

[2] All xanthates were crosslinked with zinc sulfate.

Although a good estimate of the potential for rubber reinforced with cereal products cannot be made until work under way is completed, it is believed that the potential market could amount to hundreds of millions of pounds per year.

Cereal Products in Paper

(A) Cationic Flour

Background

Cationic flours (aminoethyl flours) are produced by treatment of cereal flours at normal moisture content with three parts of ethylenimine, in the gaseous or atomized state, per 100 parts of flour for from 3 to 4 hours at 60° to 80° C., followed by acidification with aqueous hydrochloric acid or gaseous hydrogen chloride as shown in figure 5 (8). These cationic flours on evaluation in handsheets and in runs on our 32-inch paper machine were equivalent to premium-quality commercial cationic corn starch and an experimental aminoethyl starch in improving strength properties of paper and in increasing pigment (filler) retention (7). No significant differences in performance were noted for cationic soft wheat, corn, and sorghum flour.

Progress

Early in 1970 we negotiated a Memorandum of Understanding with the Dow Chemical Company in which it was agreed that they would work on the development of a commercial process for making cationic flours, and we would evaluate the products made during the course of the development work. As a consequence of this cooperative work a process for making up to 300 pounds

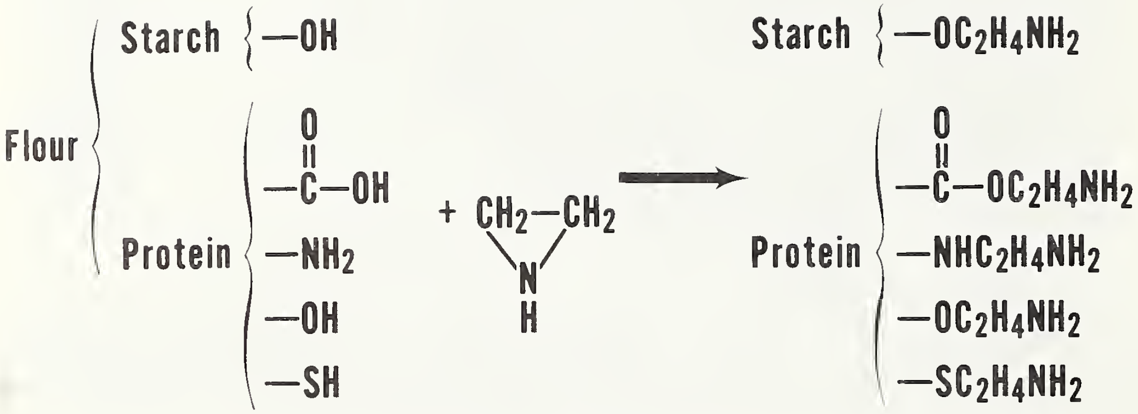

Figure 5.--Aminoethylation of cereal flour.

of cationic flour per hour was developed. In this process outlined in figure 6 flour is mixed at ambient temperature with three to four parts by weight of vaporized ethylenimine per hundred parts of flour. Residence time in the mixer, which has a horizontal shaft with radial vanes rotating at 1,150 r.p.m., is 1 minute. The treated flour is then piped to one or the other of two closed reactors equipped with slow-speed ribbon agitators where it is heated to 95° to 100° C. for 1 hour. The flour is then discharged into a closed holding bin where it is allowed to cool to 35° C. before acidifying with gaseous hydrogen chloride.

The performance of cationic soft wheat flour and cationic yellow corn flour made in Dow's market development plant and a high-quality commercial cationic starch when used as a wet-end additive for pigmented bag paper made on our 32-inch paper machine is given in table 2. On the whole, the cationic flours appear to be equivalent to each other and to the commercial product except that the flours were more effective than the latter in reducing B.O.D. in the white water. Tensile increases in the cross machine direction (CM) of the sheet are greater than in the machine direction (MD) because the sheet is always weaker in the cross machine direction.

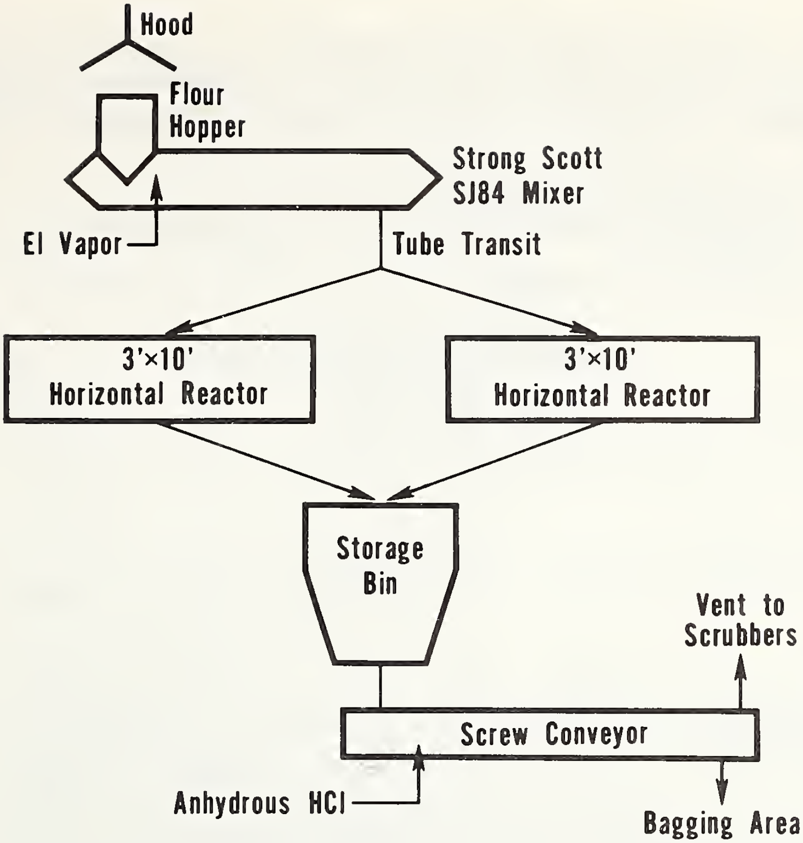

Figure 6.--Schematic diagram of market development plant for making aminoethylated (cationic) cereal flours.

Dow has provided assistance and cationic flours to interested producers and users. As a consequence, we have been invited to observe some mill runs arranged by industry. Unfortunately, all these runs have been with cationic corn flour. Therefore, we are having sufficient quantities of cationic soft wheat flour made for mill runs and are now negotiating with the paper industry for such mill trials. The results of one mill trial with cationic yellow corn flour are summarized in tables 3 and 4. The cationic corn flour was equal to or better than the commercial cationic starch in improving strength and in retaining pigment as measured by the ash values. In reducing total solids, ash, and B.O.D. in the white water, the cationic flour was definitely superior to the cationic starch. Dow estimates that at current prices for materials, equipment, and plant facilities cationic yellow corn flour made in a plant with a 15-million-pound-per-year capacity can be produced to sell for 13 cents per pound. The current selling price for comparable quality cationic corn starch is 16 to 17 cents per pound and for cationic potato starch 19 to 20 cents per pound. Unless some technological advantage is found for cationic wheat flour, corn flour will be the raw material of choice if the cost of wheat flour is not brought in line by shifts in market prices, use of wheat certificates, or through freight differentials. The whiter color of cationic wheat flour might give it some advantage over cationic corn flour in making very white papers. This possible technological advantage is being investigated.

Table 2.--Performance of cationic cereal products as wet-end additives[1]

Additive[2]	Paper properties Percent increase over control Burst	Tensile[3] MD	 CM	 Ash	White water Suspended solids	 B.O.D.
					Percent	Mg./liter
Cationic soft wheat flour[4]	30	19	30	17	0.018	69
Cationic corn flour[4]	32	15	31	13	0.019	70
Commercial cationic corn starch	32	14	34	15	0.022	95

[1] Runs made on the Northern Laboratory's 32-inch paper machine with pigmented bag paper furnish.

[2] All products added at the 1 percent level based on dry pulp.

[3] MD and CM = machine direction and cross machine direction of the sheet, respectively.

[4] Made in Dow's market development plant. Ethylenimine content 3.5 percent.

Table 3.--Physical properties of pigmented bag paper made in mill runs

Wet-end additive[1]	Paper properties Burst factor	Breaking length MD	 CD	 Ash
		Meters	Meters	Percent
Cationic aminoethyl corn flour	29	6,170	3,100	2.9
Commercial cationic starch	27	5,860	3,170	2.2

[1] Additional level 1 percent based on pulp.

Table 4.--White water analyses from mill runs of pigmented bag paper

	White water analyses			
		Ash		
Wet-end additive[1/]	Total solids Lb./1,000 gal.	Lb./1,000 gal.	Due to pigment Lb./1,000 gal.	B.O.D. Mg./liter
Cationic amino-ethyl corn flour	11.6	5.4	1.1	46
Commercial cationic starch	16.4	7.6	3.3	52

[1/] Additional level 1 percent based on pulp.

The potential market for cationic flours at 13 cents per pound in papermaking is estimated to be between 50 and 100 million pounds per year on the basis of two independent surveys.

(B) Graft Copolymers of Starch

Background

Graft polymers of starch are produced by creating free radicals on starch that serve as sites for the addition polymerization of vinyl-type monomers (M). The free radicals may be created by treating starch with high energy radiation as shown in figure 7 or with certain chemical agents such as ceric salts.

Numerous graft polymers of starch have been produced in our Laboratory and at General Mills and Stanford Research Institute in contracts with us (3,4,5,6,9). Several of these graft polymers show excellent potential as thickening agents and flocculating agents for a wide variety of industrial applications. However, until recently no graft polymers with good potential for papermaking applications were found.

Progress

During the past 2 years our Laboratory and General Mills, under a contract agreement with us, have developed graft polymers of starch which show excellent potential, at very low levels of addition, as pigment retention aids in making filled papers. Currently about 10 million pounds of synthetic polymers costing $1.25 and up per pound are used annually in the United States for such purpose, and the market is growing rapidly. It is estimated that the graft polymers can be produced to sell at considerably lower prices. Moreover, the graft polymers performed as well or better when evaluated on our 32-inch paper machine. Typical of their performance are the results given (table 5) for one of the graft polymers which contained 20 percent grafted polyacrylamide and 11 percent grafted poly(2-hydroxy-3-methacryloyloxypropyltrimethylammonium chloride).

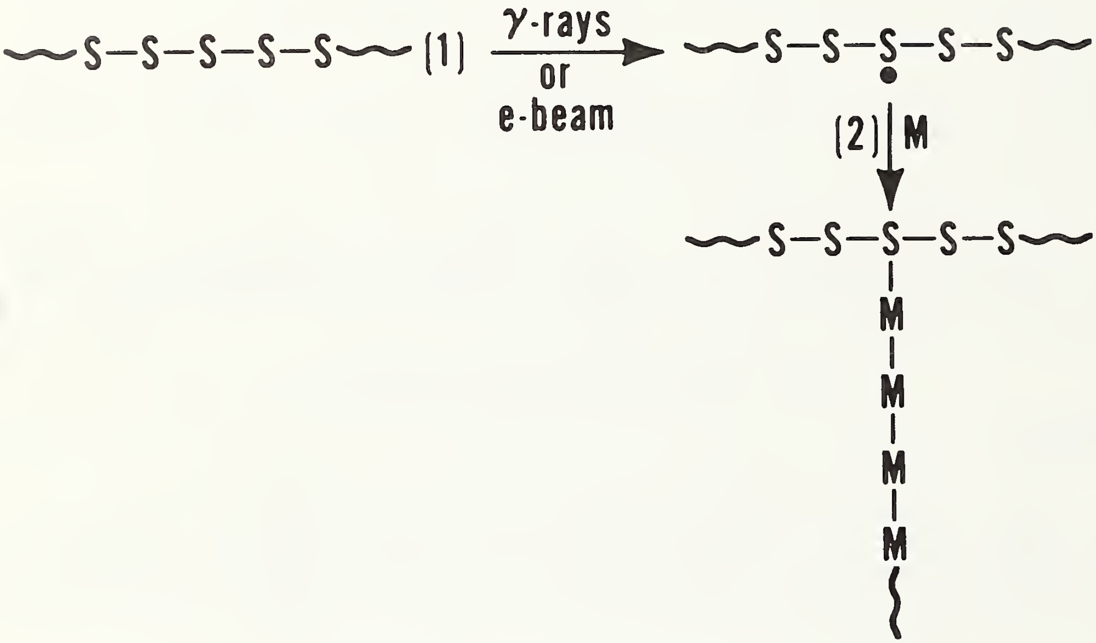

Figure 7.--Graft polymerization of vinyl or acrylic monomers (M) onto starch.

The graft polymer was equal to the synthetic polymer at the low and intermediate levels of addition and superior to it at the high level in reducing solids in the white water. The graft polymer was superior to the synthetic polymer at all levels of addition in pigment retention as measured by the ash values.

In other work on graft polymers conducted for us under contract at Stanford Research Institute, graft polymers of starch containing either butadiene or styrene in combination with acrylonitrile, acrylamide, or acrylic acid have been made which show in laboratory screening tests some potential either as wet-web strengtheners for paper or as water-resistant coating adhesives for clay-coated paper. Selected products with best potential for these applications were recently sent to our Laboratory for

Table 5.--Cationic starch graft terpolymer[1] vs. commercial synthetic polymer. Clay retention in paper

(10 percent clay, pH 5.5)

Level of addition	Total elapsed time	Solids in white water Terpolymer	 Synthetic	Ash in paper Terpolymer	 Synthetic
Percent	Min.	Percent	Percent	Percent	Percent
0	12	0.051	---	3.8	---
0.025	21	0.040	0.039	7.1	6.2
0.050	32	0.034	0.037	6.9	6.5
0.10	42	0.029	0.037	7.1	6.5

[1] The terpolymer contains 20 percent grafted polyacrylamide and 11 percent grafted poly(2-hydroxy-3-methacryloyloxypropyltrimethylammonium chloride).

more complete evaluation. The wet-web is the paper coming off the forming wire on the paper machine. In making newsprint, about 20 percent of comparatively costly long-fibered pulp has to be added to the groundwood to achieve enough wet-web strength to produce the paper at high enough speed to be practical. An additive which could replace all or part of the long-fibered pulp could command a multimillion-pound-per-year market if priced right. The water-resistant coating adhesive field, now dominated by rubber latices and casein, constitutes another multimillion-pound-per-year potential market for graft polymers of starch.

The pigment retention aids and experimental wet-web strengtheners and water-resistant coating adhesives with equal effectiveness can be made from either corn starch or wheat starch. Therefore, use of wheat starch to produce the graft polymers should they prove commercially acceptable will depend on its price in relation to corn starch.

Literature Cited

(1) Buchanan, R. A., Katz, H. C., Russell, C. R., and Rist, C. E. Starch in rubber. Powdered elastomers from starch-encased latex particles. Rubber J. 153(10):28, 30, 32, 35, 88-91. 1971.

(2) Buchanan, R. A., Weislogel, O. E., Russell, C. R., and Rist, C. E. Starch in rubber. Zinc starch xanthate in latex masterbatching. Ind. Eng. Chem. Prod. Res. Develop. 7(2):155-158. 1968.

(3) Fanta, G. F., Burr, R. C., Russell, C. R., and Rist, C. E. Graft copolymers of starch. I. Copolymerization of gelatinized wheat starch with acrylonitrile. Fractionation of copolymer and effect

of solvent on copolymer composition. J. Appl. Polym. Sci. 10(6): 929-937. 1966.

(4) Fanta, G. F., Burr, R. C., Russell, C. R., and Rist, C. E. Graft copolymers of starch and poly(2-hydroxy-3-methacryloyloxypropyltrimethylammonium chloride). Preparation and testing as flocculating agents. J. Appl. Polym. Sci. 14(10):2601-2609. 1970.

(5) Fanta, G. F., Burr, R. C., Russell, C. R., and Rist, C. E. Graft copolymers of starch with mineral acid salts of dimethylaminoethyl methacrylate. Preparation and testing as flocculating agents. J. Appl. Polym. Sci. 15(8):1889-1902. 1971.

(6) Gugliemelli, L. A., Weaver, M. O., Russell, C. R., and Rist, C. E. Base-hydrolyzed starch-polyacrylonitrile (S-PAN) graft copolymer. S-PAN-1:1, PAN M.W. 794,000. J. Appl. Polym. Sci. 13(9):2007-2017. 1969.

(7) Heath, H. D., Ernst, A. J., Hofreiter, B. T., and Rankin, J. C. Cationic aminoethyl cereal flours as wet-end paper additives. Tappi 52(9):1647-1651. 1969.

(8) Rankin, J. C., Holzapfel, M. M., Russell, C. R., and Rist, C. E. Preparation and properties of cationic cereal flours. Tappi 52(1): 82-86. 1969.

(9) Reyes, Z., Clark, C. F., Comas, M., Russell, C. R., and Rist, C. E. Continuous production of graft copolymers of starch with acrylamide and acrylic acid by electron preirradiation. Nucl. Appl. 6(5): 509-517. 1969.

(10) Stephens, H. L., Roberts, R. W., Reed, T. F., and Murphy, R. J. Starch-elastomer masterbatches. Preparation, properties, and process design. Ind. Eng. Chem. Prod. Res. Develop. 10(1):84-92. 1971.

(11) Stephens, H. L., Murphy, R. J., and Reed, T. F. The use of starch as a reinforcing filler for rubber. Rubber World 161(2):77-81. 1969.

(12) U.S. Agricultural Research Service. Report of Sixth National Conference on Wheat Utilization Research, Oakland, Calif., November 5-7, 1969. U.S. Dept. Agr., Agr. Res. Serv., ARS 74-54, 200 pp. 1970.

PELLETIZED ACTIVE CARBON FROM WHOLE WHEAT

By Bruce V. Ettling, Mark F. Adams, Dorothy J. Schecter, and R. A. V. Raff,
Washington State University

The Engineering Research Division of Washington State University has undertaken a project to determine the feasibility of producing a granular active carbon directly from whole wheat kernels. The active carbon could be a fairly large outlet for wheat in the industrial market. Active carbon is used for purifying domestic water and various waste waters, for taking gases and odors out of air supplies, and for decolorizing a number of industrial and food products.

Active carbon can be made from nearly any carbonaceous material, that is, any plant or animal parts. For economic and some technical reasons, most active carbon is made from wood wastes or other wastes such as coconut shells or fruit pits. For many uses, the carbon is preferred in a granular form rather than in a powdered form. Thus if made from sawdust, the carbon must be pressed into pellets of the desired size. If made from nut shells, the shell must first be broken and then screened to get the pieces of the desired size.

Wheat offers an opportunity to make a pelletized carbon, directly from the kernel, that has a good granule size, flows and handles easily and needs not be either crushed or pressed into pellets.

There are two ways of preparing active carbon. In one, charcoal is first produced and then activated with steam or carbon dioxide (two step process). In the other (single step process) the raw material is treated with a solution of activating chemicals and is then heated in an inert atmosphere, after which it is leached with water or acids or both and dried. The latter approach has been used in this study. In addition to the carbon which is produced, appreciable quantities of volatile products are driven off from the wheat during the heating.

Experimental

Whole wheat (Gaines variety) was used throughout the study. The wheat was first screened to remove extraneous material. A 100-gram sample of wheat was weighed out and either carbonized without treatment or carbonized after a preliminary treatment. The treatment consisted of soaking the wheat in zinc chloride or phosphoric acid for a particular duration at a specified temperature (conditions are given in table 1). The untreated wheat or the treated wheat with the treatment chemical was poured into a quartz tube. The tube was put into a muffle furnace and fitted with a gas inlet and a condenser (fig. 1).

TABLE 1.--Results of varying the carbonizing conditions

Trial	Sample treatment	Maximum temperature	Bulk density	Ash	Methylene blue adsorption	Percentage of Darco activity	Phenol adsorption	Percentage of Darco activity
		°C.	g./liter	Percent	mg./g. carbon		mg./g. carbon	
1	Fast heating	700	240	6.4	2.9	1.6	3.0	3.2
2	Moderate heating	700	230	6.2	11	6.1	2.9	3.1
3	Slow heating	700	240	6.0	3.8	2.1	5.0	5.3
4	3-4 Hr. soak in H_3PO_4 at 60° C., fast heating	650	280	8.6	34	19	35	37
5	3-4 Hr. soak in $ZnCl_2$ at 60° C., fast heating	650	270	2.8	43	24	75	79
6	3-4 Hr. soak in $ZnCl_2$ at 60° C., slow heating	650	290	2.5	50	28	82	86
7	3-Day soak in $ZnCl_2$ at 60° C., slow heating	650	280	1.2	71	39	93	98
8	3-4 Hr. soak in $ZnCl_2$ at 60° C., slow heating (tube inclined)	600	250	0.77	130	72	85	89
9	22 Hr. soak in $ZnCl_2$ at 80-85° C., slow heating	600	260	0.40	140	78	80	84
10	3-4 Hr. soak in $ZnCl_2$ at 85-90° C., slow heating	600	260	0.22	140	78	94	99
11	3-4 Hr. soak in $ZnCl_2$ at 85-90° C., slow heating	550	260	0.66	100	56	83	87
	Commercial Darco	---	---	---	160-210	100	91-99	100
	Commercial coconut char	---	---	---	200		160	

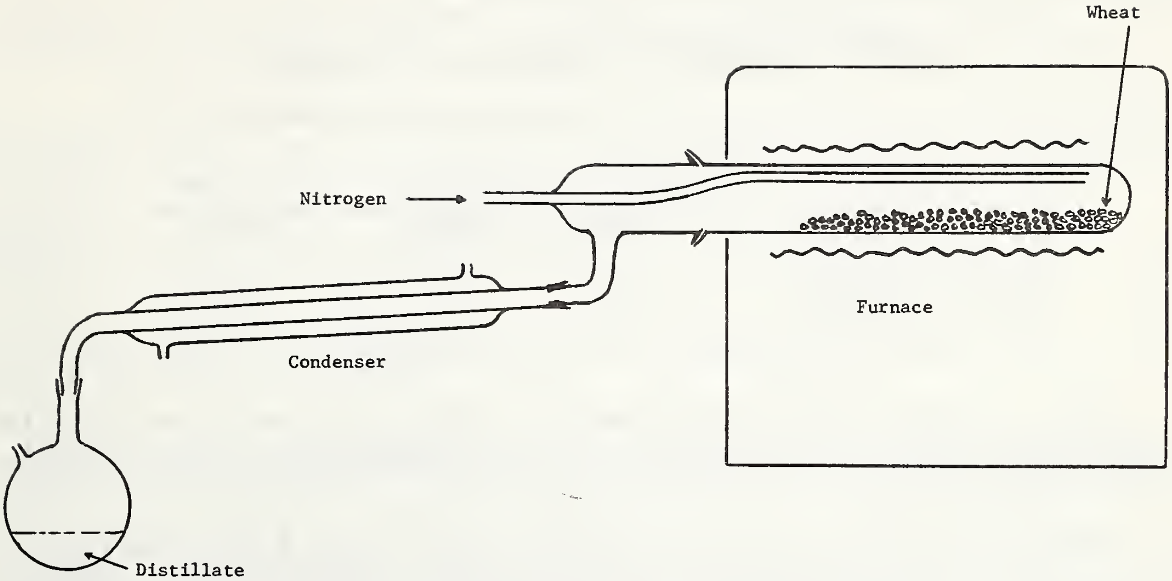

Figure 1.--Apparatus for carbonizing wheat.

The system was purged with nitrogen to remove atmospheric oxygen. The tube was heated so that the temperature of the wheat was raised either slowly or rapidly. A slow stream of nitrogen was maintained during the heating to carry decomposition products away from the wheat and into the condenser and receiving flask. The temperature was held at the maximum for 15 minutes and then the system was allowed to cool.

The char was removed from the tube with water soaking and mechanical action. The char was broken up and washed with 4 percent hydrochloric acid to remove zinc salts and then with water until neutral to methyl orange. Then the char was dried in an oven at 200° C. for several hours and held in capped jars until used.

Three methods of heating the tube were used. In the first, the temperature was allowed to rise as fast as the furnace could be heated. In the second, the temperature was held constant for 15 minutes at two points during the heating before coming to the final temperature. In the third, the temperature rise was slowed even more by pauses at additional selected points before coming to the final temperature.

When zinc chloride or phosphoric acid was used to activate the carbon, the temperature was held at 175° C. for 20 minutes to remove water before raising the temperature.

Elemental analyses were made on two of the chars (table 2). The adsorption of phenol and methylene blue were used as measures of the activity of the carbon. The carbon was ground to pass a 200 mesh sieve prior to testing in accordance with recommended procedures.

TABLE 2.--Elemental analyses of the carbon

Sample	Elemental analysis		
	Carbon	Hydrogen	Nitrogen
	Percent	Percent	Percent
Trial 3 (no $ZnCl_2$)	80.3	1.6	3.4
Trial 9 ($ZnCl_2$)	82.7	2.0	2.2

The fluid part of the condensate from trials 3, 5, and 6 was distilled to isolate the lower boiling materials. The distillates were then analyzed by gas chromatography.

The granular chars from trials 6 and 8 were tested for hardness and resistance to abrasion (table 3). Twelve pellets of char from each sample were crushed in a compression cage in an Instron tester. The maximum compressive load in grams was divided by the weight of the individual specimens to adjust for the differences in size among the specimens. Pieces of commercial coconut charcoal were tested similarly for comparison.

TABLE 3.--Physical properties of the carbon

Sample	Crushing weight (range in kg. per g.)	Percentage lost on shaking
Trial 6	68 - 190	12
Trial 8	70 - 170	7
Coconut charcoal	340 - 800	1

Portions of the char from trials 6 and 8 and commercial coconut charcoal were sieved, and 5 gram samples of the +10 mesh cut were put in a shaking machine overnight. The samples were again sieved and that part remaining on the 10 mesh sieve was weighed. The percentage of char weight remaining after shaking was a measure of the resistance to abrasion (table 3).

Discussion

The basic purpose of this study, to demonstrate the production of granular active carbon from whole wheat, has been accomplished. The carbonization process is fairly conventional and similar to the process used for carbonizing sawdust. The carbonizing experiments in this report were limited to a fixed tube rather than a rotating kiln which is used commercially. The fixed tube caused some problems such as caking of the char but still allowed the basic process to be studied. Studies on carbonizing by rotary kiln or fluidized bed are reserved for a succeeding phase of the investigation.

Table 1 lists the conditions and treatments employed in carbonizing the wheat. Bulk densities, percent ash and methylene blue, and phenol adsorption capacities are also listed. For comparison, some experimental values of commercially activated carbon have been incorporated into the table [Darco (20 X 40), Atlas Chemical Industries, Inc., and activated coconut charcoal (6 X 14) Matheson Coleman and Bell].

The yields of carbon ranged from 20 to 30 percent after workup. Some fine carbon was lost through washing.

It is readily seen that treating the wheat kernels with either zinc chloride or phosphoric acid increased the adsorption capacity of the carbon. Zinc chloride appears to be more promising than phosphoric acid as an activating agent, especially on the basis of ash content. No rigid washing procedure was developed to insure removal of the zinc chloride which may account for the differences in ash content. Phenol adsorption capacity changed little in trials 5-9 and compared favorably with Darco. Methylene blue adsorption seems to depend very much on the specific procedure of zinc chloride activation.

During the time that the wheat was soaking in the zinc chloride solution, the mixture became very dark indicating decomposition of at least some of the components of the wheat. Acidic zinc chloride is a very strong catalyst and can be expected to cause decomposition of some materials such as sugars or starch.

During the heating or carbonizing process, the zinc chloride caused more rapid and more complete breakdown of the organic matter to give carbon than when no catalyst was used. When the wheat was heated without a catalyst, much of the carbonaceous matter was distilled out of the wheat and was collected as a mixture of tar plus a watery condensate. If a maximum yield of carbon is desired, then the catalyst must be used during charring. On the other hand, if the tar and condensate are desired as by-products, the charring must be done without a catalyst which also serves as an activating agent, thus requiring a second step to produce activated carbon.

The condensate contained little or no tar when the wheat was charred with zinc chloride and was strongly acidic with a pH of less than one. The condensate from the wheat which was charred without zinc chloride contained much tar and was only weakly acidic with a pH of about 5. The strong acidity is due to hydrochloric acid as well as some zinc chloride distilling over into the condensate during the carbonizing process. The weak acidity is a result of organic acids such as acetic and formic acids that are formed during the decomposition of the wheat components. Weak organic acids are also present in the condensate from the zinc chloride process.

The condensates from the wheat carbonized either with or without zinc chloride gave positive 2,4-dinitrophenylhydrazine tests for carbonyl compounds. The same condensates did not give a positive test for phenols by color formation with a diazotized amine. A positive test for alcohols (probably mostly methyl alcohol) was obtained with the condensate which was formed without zinc chloride.

An infrared spectrum of the tar from the wheat carbonized without zinc chloride showed a broad strong OH band which could be attributed to alcohols, phenols, and possibly moisture in the tar. There was also a broad band in the carbonyl region suggesting the presence of aldehydes, ketones, acids, and a few other less likely functional groups.

Carbon produced without an activator showed very poor activity by phenol or methylene blue adsorption (trials 1, 2, 3 in table 1). Phosphoric acid as the activator gave only moderate activity (trial 4 in table 1).

Zinc chloride is the most commonly used activator. There are technical reasons, such as favorable melting and boiling temperatures, solubility, and ease of recovery (recycling), that favor its use. Zinc chloride in the single step process functions both as a catalyst for the decomposition of the organic matter and as an activator of the carbon. Pelletized active carbon with activity comparable to a commercial activated carbon (Darco 20 X 40) was produced by the zinc chloride process. The best activity was found when the wheat was carbonized with a relatively slow rate of increase of temperature and with a maximum temperature of 600° C. or higher. Soaking periods of from 3 to 4 hours up to 22 hours and temperatures of 60-90° before carbonization gave good activity. A laboratory grade of activated coconut charcoal was also evaluated for comparison.

The granular carbon from the whole wheat was compared with the laboratory grade of coconut charcoal for hardness and abrasion resistance. The maximum compressive load per gram of carbon needed to crush the wheat char granules was about one-fifth that needed to crush the coconut charcoal. In the abrasion test, after being shaken overnight, there was a 1 percent loss from the coconut charcoal but 7 and 12 percent losses from two wheat carbon samples. Thus, the wheat carbon granules are not as hard as charcoal made from coconut shells; however, the wheat char could be handled and poured in the laboratory without a significant amount of breakage or dusting. The attrition of the wheat char from abrasion is above the maximum for commercial carbons.

The yields of carbon ranged from 20 to 30 percent of the starting weight of the wheat after washing and drying the carbon. Much fine carbon was lost because of the need to break up the cake of char. When a rotary kiln is used, the char should not cake as much, and more definite yield data can be obtained.

Conclusions

The following conclusions were reached:

(1) Granular activated carbon can be produced from whole wheat in a fairly simple arrangement of heating in the presence of zinc chloride to decompose the carbonaceous material, then continuing the heating up to 600° C. to activate the char.

(2) The resulting carbon has activity comparable to that of a commercial activated carbon.

(3) The granules of carbon from wheat are not as strong as granules of coconut char.

(4) The strength and abrasion resistance of the char should be improved.

(5) Standard process steps, such as the use of a rotary kiln, need to be investigated.

(6) The reuse of the zinc chloride will have to be studied before a good cost figure can be calculated for the process.

Acknowledgment

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NUTRIENT CONTRIBUTION OF WHEAT PRODUCTS

By C. Edith Weir, Human Nutrition Research Division, Agricultural Research Service, United States Department of Agriculture

For centuries, wheat and wheat products have been recognized as important, economical, and consistent sources of nutrients in human diets. Consumption of cereal products has decreased over the past decades, and there also has been a change in type of product. Between 1955 and 1965 the household food consumption of white flour decreased by 41 percent, that of white bread by 2 percent, that of cornmeal and grits by 36 percent. At the same time, there were major increases in the consumption of rice, 44 percent; ready-to-eat cereal, 41 percent; and sweet baked goods, 65 percent (7). At the time of the 1965 survey, grain products were good sources of several critical nutrients in U.S. diets. They provided 40 percent of the thiamine, 31 percent of the iron, 20 percent of the food energy, 20 percent of the protein, 19 percent of riboflavin, and 17 percent of calcium (15). These percentages are based on the total nutritive value of foods classed as "grain products," not just the flour or cereal ingredient; that is, some of the nutrients are provided by other foods in bakery products. For example, some of the protein, riboflavin, and calcium are provided by milk, some of the calcium by leavening agents and preservatives, and some of the calories from fats and sugar in store-bought baked goods.

The proportionate share of total nutrients contributed by all cereal products to the diet is gradually decreasing. Wheat comprises over 80 percent of the cereal products consumed as food in the U.S. diet. Preliminary estimates have been made of the contribution of wheat in U.S. diets in 1971 (1). Based on the disappearance of wheat products from the marketplace, wheat is expected to provide 15.3 percent of the calories, 14.8 percent of the protein, 0.9 percent of the fat, 28.1 percent of the carbohydrate, 2.6 percent of the calcium, 9 percent of the phosphorus, 17 percent of the iron, 22.8 percent of the thiamine, 11.3 percent of the riboflavin, and 16.3 percent of the niacin. When the enrichment of wheat products is included in the values, iron is increased from 17.0 to 19.2 percent, thiamine from 22.8 to 24.7 percent, riboflavin from 11.3 to 11.6 percent, and niacin from 16.3 to 17.2 percent. This represents an overall decrease from the 1970 figures and reflects a concurrent increase in meat supplies in 1971, particularly a 9 percent increase in the pork supply.

The data in this presentation are from two studies on the nutrient composition of wheat recently completed by the Human Nutrition Research Division. One of the studies (13,14) dealt with the nutrient composition of hard, soft, and durum wheat grains selected from different growing areas, and the flours milled from the wheat. Another part of the study analyzed the nutrient content of flours, bread, baked goods, cereals, and other wheat based products purchased in 10 cities located in different parts of the United States. The other study (8) followed changes in B-vitamin content in wheat during 3 years of ambient temperature storage in Kansas while subjected to different fumigation treatments. In addition, milling fractions and bread baked from the wheat flour were assayed for B-vitamin content.

Major losses occur in the B-vitamin and mineral content of wheat during the milling process. Retentions in hard and soft wheat flours are directly related to the percent extraction of the flour with less than 20 percent of the B-vitamins remaining in 60 percent extraction flour (fig. 1). Thiamine, riboflavin, niacin, and vitamin B_6 retention is shown for hard wheat flour at 57 percent extraction and soft wheat flours at 75 and 54 percent extraction (2,4,9,17). Ten percent or less of the initial B-vitamin content remains in 54 percent extraction soft wheat flour. However, almost 40 percent of the riboflavin and niacin remain in semolina--about 42 percent extraction--suggesting that these vitamins are more evenly distributed throughout the endosperm of the durum wheat than of the hard and soft wheats.

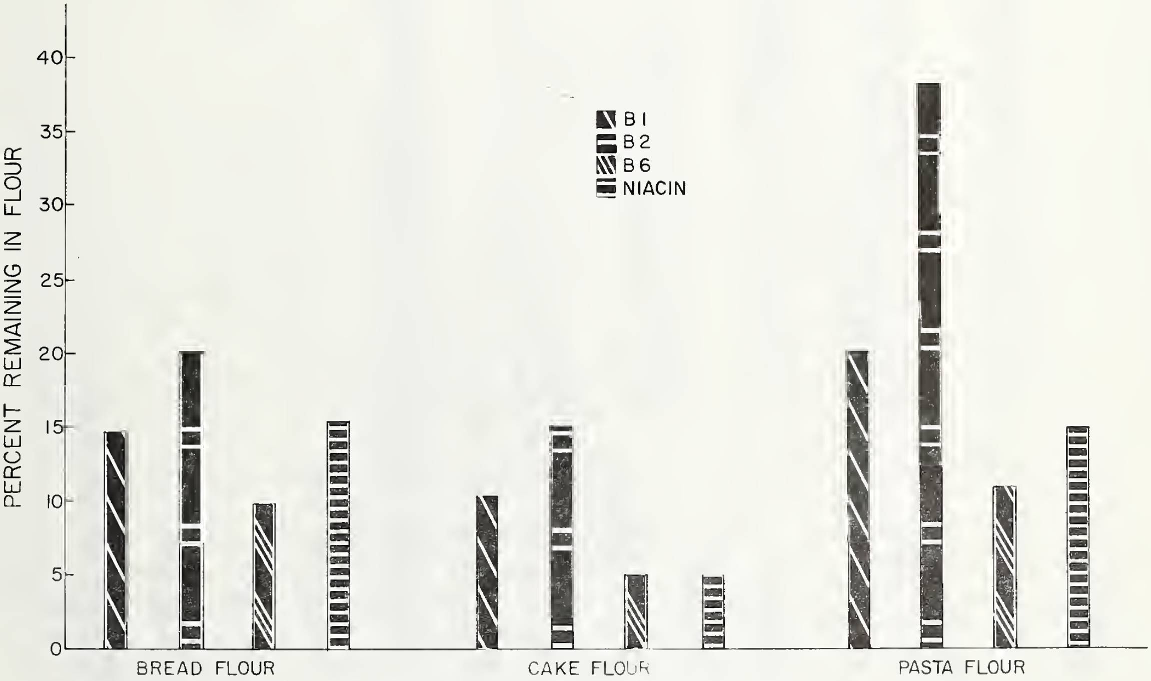

Figure 1.--Effect of milling on vitamins.

The distribution of vitamins among the different fractions from milling is shown in figure 2. The wheat was milled experimentally to yield about 16 percent bran, 9 percent shorts, 8 percent low grade flour, and 67 percent patent flour (8). Almost two-thirds of the niacin and vitamin B_6, one-half of the riboflavin, and one-third of the thiamine and tocopherols were removed in the bran (5,10,12). Approximately one-half the thiamine was in the shorts as were one-quarter of the riboflavin, vitamin B_6, and tocopherols. About one-third of the total tocopherols remained in the patent flour. Of this, over two-thirds was epsilon tocopherol and only 7.5 percent was alpha tocopherol. The B-vitamins remaining in the patent flour were from 13 to 18 percent of the initial thiamine, riboflavin, and niacin, and less than 10 percent of the vitamin B_6. Thus, the milling fractions are rich sources of B-vitamins and tocopherols.

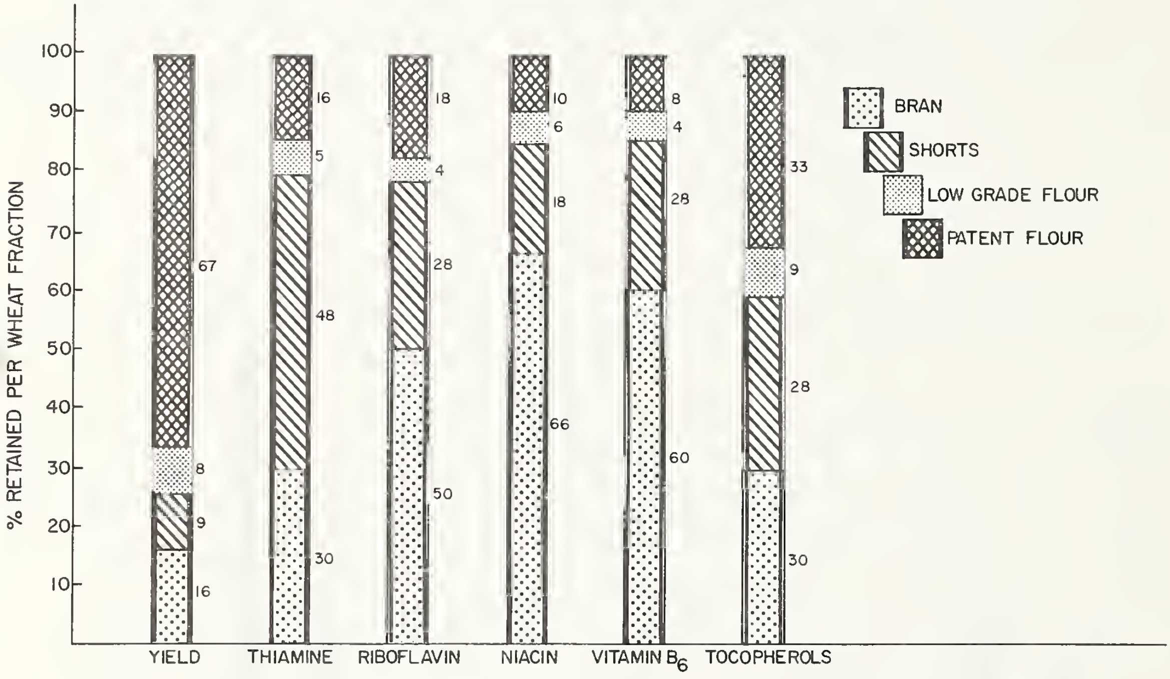

Figure 2.--Distribution of vitamins among milling fractions.

The loss in mineral content during processing is also severe (fig. 3). In flour from hard wheat, less than 25 percent of the iron, phosphorus, potassium, copper, magnesium, manganese, and zinc were retained and slightly more of the calcium, cadmium, chromium, nickel, and tin (3,18). Similar losses were found in flour from soft wheat with greater losses in the more refined flours. The National Nutrition Survey of 1968 and the 1965-1966 (16) Food Consumption Survey of individual food intakes both show that calcium and iron are likely to be present in the diet in inadequate amounts. Information on magnesium requirements and content of food is inadequate. What data exist indicate that magnesium is likely to be present in insufficient amounts in the diet. Even less is known about the nutritional adequacy for zinc. Considerable interest is presently being centered on this mineral because of recently developed information on its role in protein synthesis and wound healing. Chromium is another trace element for which dietary allowances will probably soon be recommended. Chromium is necessary for proper functioning of insulin and in maintaining normal glucose tolerance levels in humans. Its naturally occurring form in wheat is much more active than the elemental form (11). It has been suggested that the decrease in chromium stores in man with age may be associated with a decrease in glucose tolerance associated with aging and may reflect a chronic low level intake of chromium throughout life. At birth, the liver contains large stores of chromium which are gradually depleted. This depletion is particularly marked with successive pregnancies in women and may help explain the greater incidence of diabetes in women who have had several pregnancies. Several of the other minerals that occur at low levels in the diet may become critical as refined and formulated foods make up larger proportions of the foods eaten. Marginal intakes of trace minerals throughout life may cumulate in health problems in adulthood. These results of longtime small inadequacies are real, even though hard to identify and demonstrate.

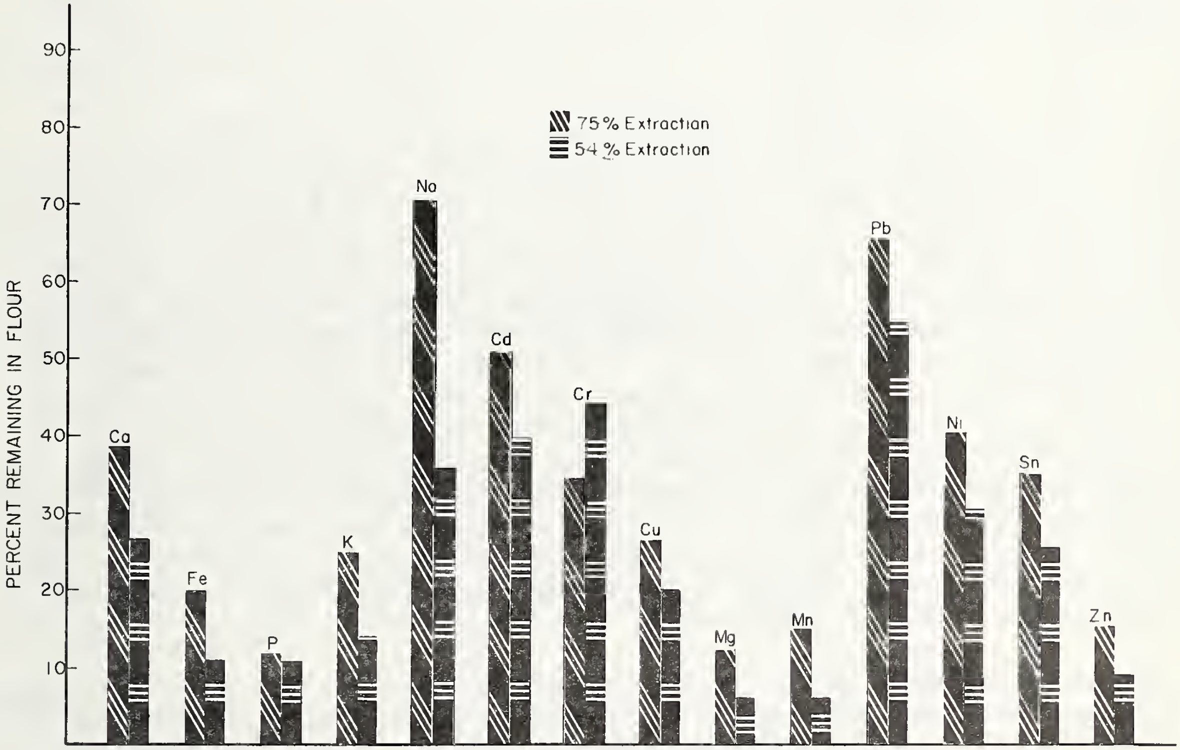

Figure 3.--Effect of milling on minerals in soft wheat flour.

Food habits, higher incomes, and the increased availability and greater variety of prepared foods have combined to increase the consumption of meats, fats, and sugars. The increased intake of fat and sugar has been indicted in the increased incidence of obesity and heart disease--both major health problems in the United States. In 1965 in the diets of adult men

(34-54 years), fat provided 45 percent of the calories, protein 16 percent, and carbohydrates 39 percent (15). Data on disappearance of foods from the marketplace suggest that the proportion of calories from fat may be higher in 1971 than it was in 1965 (1). Unfortunately, there are no more recent data on food consumption than 1965 and none are likely until there are funds for another Nationwide Food Consumption Survey similar to the one in 1965. The lack of food consumption data is a serious handicap to sound nutritional evaluation of the U.S. dietary. Of particular concern are the diets of teenagers whose intake of high fat foods, such as snacks, French fries, ice cream, and doughnuts, is thought to have increased appreciably. Estimates of over 50 percent of calories from fat have been made for this age group.

During the past 15 years, many concerned groups have recommended a reduction in fat consumption. A concerted effort to accomplish this decrease is likely. In December of 1970, the Inter-Society Commission for Heart-Disease Resources recommended a reduction to less than 35 percent of total calories from all fats (6). A reduction of this magnitude in fat intake would need to be balanced by an equivalent calorie increase in carbohydrate consumption, because it is unlikely that the protein intake would be appreciably greater. A reduction in fat intake from 45 to 35 percent of the calories would mean an increase in carbohydrate consumption of 67 grams or from 251 grams to 318 grams per day (table 1). This would correspond to an increase from 1,000 calories per day to 1,275 calories from carbohydrate sources or the equivalent of an additional 1/4 pound per day of wheat flour. The same Inter-Society Report recommends that baked products contain less fat and indeed this would be essential if the total fat intake is to be reduced. In addition, the amount of sugars and sirups used in the products would need to be limited. Sugars, particularly sucrose and fructose, have been implicated in the undesirable changes in fat metabolism associated with heart and vasculatory disease in some individuals. The human body cannot store carbohydrate as such without conversion to fat. Calories from carbohydrate in excess of about 800 cannot be used up directly as energy. For this reason and others, it is important that every effort be made that the calorie deficit resulting from decreased intake of fat not be made up by increasing the intake of sugar. Diets high in sugar have resulted in a higher proportion of body fat in rats when compared with diets of equal caloric value when the carbohydrate was starch. Also, eating sweet foods may increase the number of tooth cavities in children.

Sugar consumption in the United States has continually increased during this century. Preliminary estimates for 1971, based on disappearance of foods from the market, are that sugar consumption may be as high as 141 grams per capita per day (1), which is well over the 52 percent of total carbohydrate from sugar estimated in 1969. Comparable figures for other countries are 180 grams per day in the United Kingdom, 125 grams per day in Switzerland, and 85 grams per day in West Germany. All these countries have programs in effect to reduce sugar consumption. There has been no appreciable change in the amount of sugar consumed in Switzerland for 8 years. However, sugar consumption in Germany and the United Kingdom is still going up.

TABLE 1.--Caloric intake for adult man 35-54 years

Energy source	1965 Diets[1/]			Proposed diets[2/]		
	Percent of calories	Calories	Grams	Percent of calories	Calories	Grams
Fat	45	1,170	130	35	910	101
Protein	16	412	103	16	412	103
Carbohydrates	39	1,004	251	49	1,274	318

[1/] Food intake and nutritive value of diets of men, women, and children in the United States, spring 1965, USDA. ARS 62-18 (March 1969).

[2/] Proposed diet with 35 percent calories from fat. This moderate reduction in fat intake is less than recommended by many groups such as the Inter-Society Commission on Heart (18).

To summarize this discussion: wheat and wheat products continue to make valuable nutritional contributions to the U.S. diet. The greater proportion, usually more than three-quarters, of the initial B-vitamin and mineral content is lost during processing. The entire wheat industry is facing an unusual opportunity to play an increasing and valuable role in human nutrition, provided they can provide high quality well-flavored foods, low in fat, without excessive sugar content at a competitive price and with the convenience characteristics demanded by consumers.

Literature Cited

(1) Friend, B. Nutritional review. National Food Situation, No. 138, 25-30. November 1971.

(2) Hepburn, F. N. Nutrient composition of selected wheats and wheat products. VIII. Thiamin and riboflavin. Cereal Chem. (accepted for publication).

(3) Hepburn, F. N. Nutrient composition of selected wheats and wheat products. IX. Macro mineral elements. Cereal Chem. (accepted for publication).

(4) Hepburn, F. N., and Tulloss, J. H. Nutrient composition of selected wheats and wheat products. VII. Total and free niacin. Cereal Chem. 48:369. 1971.

(5) Hewston, E. W., and Toepfer, E. W. Effect of fumigation on wheat in storage. Thiamin, riboflavin, and niacin components of wheat and wheat

products. Unpublished data from The Human Nutrition Research Division, ARS, USDA, Beltsville, Maryland, 1969.

(6) Inter-Society Commission for Heart-Disease Resources Report. Primary prevention of the atherosclerotic diseases. Circulation XLII, A55-A95, December 1970.

(7) LeBovit, C. U.S. diets and enrichment. Talk at Symposium on Enrichment of Food with Nutrients, Amer. Chem. Soc., Div. of Agriculture and Food Chemistry, Chicago, Illinois, September 11, 1967.

(8) Matthews, R. H., Fifield, C. C., Hartsing, T. F., Storey, C. L., and Dennis, N. M. Effects of fumigation on wheat in storage. I. Physical measurements of flour. Cereal Chem. 47:579. 1970.

(9) Polansky, M. M., and Toepfer, E. W. Nutrient composition of selected wheats and wheat products. IV. Vitamin B-6 components. Cereal Chem. 46:664. 1969.

(10) Polansky, M. M., and Toepfer, E. W. Effect of fumigation on wheat in storage. III. Vitamin B-6 components of wheat and wheat products. Cereal Chem. 48:392. 1971.

(11) Roginski, E. E., Toepfer, E. W., Polansky, M. M., and Mertz, W. Chromium and glucose tolerance activity in wheat. Fed. Proc. 23:255. 1971.

(12) Slover, H. T., and Lehmann, J. Effect of fumigation on wheat in storage. IV. Tocopherols. Cereal Chem. (accepted for publication).

(13) Toepfer, E. W., Hewston, E. M., Hepburn, F. N., and Tulloss, J. H. Nutrient composition of selected wheats and wheat products. I. Description of samples. Cereal Chem. 46:560. 1969.

(14) Toepfer, E. W., Polansky, M. M., Eheart, J. F., Slover, H. T., and Morris, E. R. Nutrient composition of selected wheats and wheat products. XI. Summary. Cereal Chem. 49:173. 1972.

(15) U.S. Department of Agriculture. Dietary levels of households in the United States, spring 1965. A preliminary report. ARS 62-17, January 1968.

(16) U.S. Department of Agriculture. Food intake and nutritive value of diets of men, women, and children in the United States, spring 1965. ARS 62-18, March 1969.

(17) Weir, C. E. Nutrient profile of wheat as affected by milling and processing. Talk given at VIIIth International Congress of Nutrition, Prague, Czechoslovakia, August 28-September 5, 1969.

(18) Zook, E. G., Greene, F. E., and Morris, E. R. Nutrient composition of selected wheats and wheat products. VI. Distribution of manganese, copper, nickel, zinc, magnesium, lead, tin, cadmium, chromium, and selenium as determined by atomic absorption spectroscopy and colorimetry. Cereal Chem. 47:720. 1970.

VALUE OF WHEAT IN PREVENTING HIGH CHOLESTEROL LEVELS

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Introduction

It has been recently stated that atherosclerosis, which is characterized by the accumulation of cholesterol and other fatty substances in the walls of large blood vessels, is the leading cause of death in the United States and in other highly developed countries. The disease is almost universally present in our population from adolescence onward. Those with an extensive form of this disease become candidates for heart attacks and angina pectoris--these occur when the coronary arteries are severely involved--and for strokes--these occur when the cerebral arteries are involved. More than 600,000 deaths occur in this country from coronary ischemic heart disease, and more than 200,000 from atherosclerosis in other sites (mainly strokes). Over 160,000 of the heart deaths occur in persons--mostly males--under 65 years of age.

In the United States today, a male under the age of 60 has one chance in five of developing artheriosclerotic ischemic heart disease. Almost one-third of the initial heart attack cases die within a few hours and more than 60 percent die before they can even be brought to medical attention. The outlook for the survivors is also gloomy (7).

That diet, at least insofar as it influences the levels of blood cholesterol and other lipids, is involved in the pathogenesis of atherosclerotic vascular disease, derives from the finding that elevation of blood cholesterol leads to the induction of atherosclerosis in the laboratory animal. Certain components of the diet have been implicated in the development of increased levels of serum cholesterol and triglycerides and the resulting involvement in atherosclerosis. However, there is confusion in the minds of the consumers as to just which foods should be eliminated and which ones can be eaten. A brief look at some of the published reports will give an idea as to what has already been found and how this relates to our diet.

The effect of the type of fat in the diet has been studied extensively by many investigators (1,6,15). These investigations followed the discovery made by three independent laboratories that levels of serum cholesterol could be lowered effectively by using increased amounts of polyunsaturated fats in the diet. However, cholesterol is not the only component of the serum lipids that reflects dietary change; the triglycerides and phospholipids are also involved. Albrink and Man (3) reported an increase of serum triglycerides and a decrease in serum cholesterol when an atherosclerotic patient was changed to a diet that contained 8-1/2 percent of the calories supplied as fat.

The type of carbohydrate in the diet also appeared to exert a pronounced effect on the metabolism of circulating lipids. In a series of papers, Yudkin, Roddy, and Morland (23,24,25) demonstrated an excellent statistical relationship among sugar intake, myocardial infarction, and atherosclerotic disease. The investigations of Kuo and Basset (17), Kaufmann et al. (14), Hodges and Krehl (13), and Anderson (4) clearly showed that the interchange of starch (vegetable and cereal starches) with sucrose had a marked effect on serum lipids, particularly on serum triglycerides. Portman et al. (19) reported that rats fed diets containing sucrose, glucose, or fructose as the carbohydrate (with added cholesterol and cholic acid) had higher serum and liver cholesterol and serum β-lipoprotein concentrations than did control rats fed diets with corn starch substituted for the sucrose. Groen and his workers (11) reported that normal subjects, when fed low fat natural diets containing either bread or sucrose as the carbohydrate source, had a higher serum cholesterol level on the sucrose diet than on the bread diet. On the other hand, no such effect was observed by Grande's group (10) who fed men low fat natural diets that were equal in all respects except for the substitution of sucrose for wheat and potatoes as the carbohydrate source. To keep the two diets as similar as possible, gluten was added to the sucrose diet in an amount comparable with that in the wheat and potato diet. In this case, the serum cholesterol level was not influenced, suggesting that gluten modified the sucrose effect on the serum cholesterol level.

There is evidence that the protein component of the diet does affect blood lipid levels. Albanese et al. (2) and Tripathy et al. (21) reported that, when the level of protein was raised in diets containing principally animal protein along with complex and refined carbohydrates, the serum cholesterol level of the patients also increased. However, Nath and associates (18) and de Groot (8) showed that high protein diets consistently lowered the serum cholesterol level in rats, and wheat gluten had a more marked effect than casein in this respect. Walker (22) fed two groups of young women either a vegetable-protein or an animal-protein diet containing equal amounts of protein and fat and a mixture of complex and refined carbohydrates. Serum cholesterol and serum lipid phosphorus levels were lower at the end of 6 weeks for the subjects receiving the vegetable-protein diet.

In 1969, we undertook a series of experiments under the sponsorship of the Idaho Wheat Commission to reconsider the possible value of wheat in the diet of man with particular emphasis on atherosclerosis. In an initial experiment, we showed that, when rats were fed a wheat-based or a casein-based diet, both supplying marginal levels of protein (with and without added cholesterol), neither the fat level nor the type of protein influenced the serum cholesterol level (20). It appeared that the wheat-based diets produced a decrease in the cholesterol content compared with the changes in the casein-fed animals.

Therefore, this brief summary of the published reports and our data suggest that bread or wheat flour are responsible for lowering cholesterol and triglycerides in animals and man. However, it has not been clearly delineated whether the protein or the carbohydrate part of the wheat flour is more active in this regard. The identification of the part that would reduce lipid levels is of great importance to man, because wheat products are now being excluded from our diet to a greater extent than ever before.

The purpose of our research was to ascertain how various parameters in rat serum and liver were affected by feeding the animals a basal diet containing wheat protein, a moderate level of fat, and the carbohydrate sources, wheat starch (WS) and sucrose (S). Diets containing casein (C), an animal-derived protein source, prepared with different carbohydrate sources were compared with the wheat gluten (WG), a vegetable-derived protein source. The diets (NA) were isonitrogenous and isocaloric. We also studied the effect of added cholesterol and cholic acid (A diets) and the effectiveness of the protein and carbohydrate sources on returning the blood lipid values to a normal level when the cholesterol and cholic acid were removed from the diets (A/NA diets). The diets, along with tap water, were provided ad libitum. Male rats were kept on a practical-type diet until they were about 50 days old.

Results and Discussion

There have been reports indicating that a caloric level sufficiently high to maintain weight significantly elevates serum cholesterol levels and moderately elevates the serum triglyceride levels (9,16). In other words, blood lipid levels increase when weight increases. Therefore, the diets in this study were fed at levels that maintained a relatively stable weight throughout the experimental periods. The animals did not show substantial weight gains. Thus, the true cholesterolgenic properties of the diet could be better reflected.

Serum Cholesterol Analyses

Results of the experimental diets on the serum cholesterol levels of rats are seen in table 1. Examination of these data revealed some differences that, in some cases, approached statistical significance among the various groups; however, no definite pattern was detected. It is interesting to note, however, that at 12 weeks the A-WG-S was the lowest value and somewhat lower than A-WG-WS, while the A-C-WS was much greater. A-C-S is slightly higher than A-WG-S. The animal protein appears to have caused a greater increase in the serum cholesterol than the vegetable protein when a dietary source of cholesterol was consumed. When no dietary cholesterol was present, there was little difference among any of the groups. When the diets were interchanged, the cholesterol values of the A-WG-WS group at 12 weeks increased after the rats consumed the A-C-S diet. This is difficult to explain when the other data are considered.

TABLE 1.--Serum cholesterol values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./100 ml.	
Wheat gluten-wheat starch			
NA	71.1	106.5	90.1
A/NA	91.9	94.6	88.3
A	77.6	164.1	168.3
Wheat gluten-sucrose			
NA	60.5	93.1	104.9
A/NA	87.0	111.0	88.7
A	87.2	131.9	135.2
Casein-wheat starch			
NA	58.1	108.3	96.4
A/NA	83.3	97.4	101.7
A	74.4	129.6	251.3
Casein-sucrose			
NA	66.3	101.6	95.2
A/NA	83.1	101.3	104.8
A	86.9	147.3	145.3
Wheat gluten-wheat starch	83.8	---	---
Casein-sucrose			
A	---	128.5	---
Wheat gluten-wheat starch	---	---	250.7
Rat growing diet			
NA	47.2	83.5	86.0

The results of the liver cholesterol analyses are shown in table 2. The group fed A-WG-S had the lowest values, but there were no real differences between A-WG-WS and A-C-S. However, when casein replaced the wheat gluten, with wheat starch as the carbohydrate source, the liver cholesterol value increased during the last 4 weeks of the experimental period. No significant changes occurred in the liver cholesterol values when the rats' diets were interchanged.

TABLE 2.--Liver cholesterol values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./g.	
Wheat gluten-wheat starch			
NA	6.5	6.1	6.7
A/NA	7.0	6.7	8.3
A	8.6	20.5	16.1
Wheat gluten-sucrose			
NA	6.1	6.7	7.2
A/NA	6.9	7.1	7.0
A	10.1	9.2	12.2
Casein-wheat starch			
NA	5.3		8.3
A/NA	9.5	6.6	7.5
A	8.7	22.5	27.2
Casein-sucrose			
NA	7.2	6.3	6.7
A/NA	10.9	7.6	7.3
A	13.3	19.2	13.0
Wheat gluten-wheat starch	9.6	---	---
Casein-sucrose			
A	---	15.1	---
Wheat gluten-wheat starch	---	---	19.2
Rat growing diet			
NA	9.0	8.3	7.7

Table 3 shows the results of the serum triglyceride analyses. Again it is seen that the highest level of triglycerides was obtained when the casein was substituted for the wheat gluten. On the other hand, the A-WG-S group again had the lowest levels. The levels of the group fed NA-WG-WS at 12 weeks was much less than those of the group fed NA-WG-S, while the group fed the casein--NA-C-WS and NA-C-S--had the highest triglyceride levels. It is interesting to note the significant increase in triglyceride levels when the group of rats whose diet was changed throughout the experimental period was fed A-C-S for 4 weeks, after the group had consumed the A-WG-WS diet for 4 weeks. Then, when returned to the A-WG-WS diet, the triglyceride level decreased sharply. The data suggest that wheat functions by lowering the triglyceride level significantly below that produced by the animal protein and refined carbohydrate sources.

TABLE 3.--Serum triglyceride values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./100 ml.	
Wheat gluten-wheat starch			
NA	95.2	122.0	158.4
A/NA	159.1	161.0	207.7
A	140.0	533.3	230.6
Wheat gluten-sucrose			
NA	124.2	231.1	182.7
A/NA	177.3	311.1	117.3
A	267.1	294.8	180.9
Casein-wheat starch			
NA	73.4	220.0	194.5
A/NA	167.1	236.0	160.4
A	134.2	376.7	301.8
Casein-sucrose			
NA	125.5	272.3	188.4
A/NA	192.7	207.9	236.5
A	169.7	566.7	223.0
Wheat gluten-wheat starch	150.8		
Casein-sucrose			
A		469.1	
Wheat gluten-wheat starch			254.6
Rat growing diet			
NA	118.0	281.4	130.0

Table 4 presents the values for liver triglyceride. As was seen in the first three tables, the wheat starch and casein diet resulted in a higher liver triglyceride value than did A-WG-WS, A-WG-S, and A-C-S. There were no differences when the diets were interchanged. In general, the serum triglyceride values reflected the dietary regime to a greater degree than did those for liver.

TABLE 4.--Liver triglyceride values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./g.	
Wheat gluten-wheat starch			
NA	10.1	25.7	19.6
A/NA	27.2	41.0	20.8
A	34.0	44.9	36.5
Wheat gluten-sucrose			
NA	16.3	29.5	22.7
A/NA	16.4	21.8	35.4
A	26.4	29.3	39.8
Casein-wheat starch			
NA	10.7		37.3
A/NA	19.4	26.4	30.1
A	30.4	48.9	45.9
Casein-sucrose			
NA	11.3	22.0	31.4
A/NA	27.2	20.3	29.1
A	42.7	30.0	32.5
Wheat gluten-wheat starch	23.8		
Casein-sucrose			
A		31.1	
Wheat gluten-wheat starch			33.0
Rat growing diet			
NA	24.8	28.4	39.8

Table 5 shows serum phospholipid values. The A-WG-WS group had lower phospholipid values than did A-WG-S and A-C-S, while the A-C-WS group again had the highest values. It is interesting to note that, in the transition groups between 8 and 12 weeks, the ones fed diets containing wheat products adjusted toward a lower phospholipid level more effectively than did those rats fed diets containing casein.

TABLE 5.--Serum phospholipid values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./100 ml.	
Wheat gluten-wheat starch			
NA	188.4	184.7	107.2
A/NA	225.3	145.5	102.9
A	766.7	229.8	187.4
Wheat gluten-sucrose			
NA	141.0	120.1	124.3
A/NA	197.5	130.7	91.5
A	207.9	217.6	230.4
Casein-wheat starch			
NA	100.4	101.6	113.4
A/NA	175.7	114.1	125.9
A	143.1	146.9	323.2
Casein-sucrose			
NA	133.6	138.9	125.3
A/NA	198.9	125.1	149.8
A	197.2	182.5	246.1
Wheat gluten-wheat starch	193.6		
Casein-sucrose			
A		193.9	
Wheat gluten-wheat starch			272.3
Rat growing diet			
NA	95.0	110.6	144.0

It can be seen from table 6 that no significant differences existed among any of the liver phospholipid values at 12 weeks. Herman et al. (12) concluded that there appeared to be a correlation between the type and amount of dietary carbohydrate and the level of serum triglycerides. However, in their study, as well as in ours, no large changes were seen in serum cholesterol or phospholipid levels where weight changes were minimal.

TABLE 6.--Liver phospholipid values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./g.	
Wheat gluten-wheat starch			
NA	26.6	27.9	24.3
A/NA	30.0	25.3	30.6
A	35.0	39.1	28.1
Wheat gluten-sucrose			
NA	29.6	25.1	27.9
A/NA	27.4	26.5	31.5
A	32.9	33.8	34.4
Casein-wheat starch			
NA	19.2		29.0
A/NA	53.6	28.7	30.0
A	25.3	20.4	27.0
Casein-sucrose			
NA	22.9	27.6	29.7
A/NA	28.1	31.4	31.1
A	28.2	24.0	29.8
Wheat gluten-wheat starch	26.3		
Casein-sucrose			
A		25.6	
Wheat gluten-wheat starch			23.2
Rat growing diet			
NA	43.5	39.8	46.6

The results of the total serum lipid analyses can be seen in table 7. Again, the A-C-WS group had the highest values, and A-WG-S had the lowest levels. The NA diets containing WG, with either WS or S, had lower values than did the casein diets. The transition groups fed diets containing WG were also lower than the groups fed casein. The groups that had the diets interchanged are difficult to interpret as these results were opposite to those seen in the triglyceride analyses.

TABLE 7.--Total serum lipid values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./100 ml.	
Wheat gluten-wheat starch			
NA	545.7	315.0	336.0
A/NA	894.6	325.5	402.9
A	751.3	880.2	996.9
Wheat gluten-sucrose			
NA	454.5	308.3	439.6
A/NA	775.1	417.5	298.6
A	769.4	646.5	813.6
Casein-wheat starch			
NA	421.7	446.8	536.9
A/NA	722.4	404.1	517.4
A	596.4	574.1	1,631.7
Casein-sucrose			
NA	513.5	367.0	478.1
A/NA	771.9	371.9	512.8
A	648.7	786.9	854.4
Wheat gluten-wheat starch	789.7		
Casein-sucrose			
A		625.8	
Wheat gluten-wheat starch			1,312.9
Rat growing diet			
NA	350.5	273.7	360.9

Results of the analyses for total liver lipids are presented in table 8. The A-WG-WS and A-WG-S groups were lower than the A-C-WS and A-C-S groups. It is interesting to observe that the NA-C-S group had significantly higher total lipid levels than did the other comparable groups. Although total lipids are not often measured in studies such as this one, this measurement appears to reflect dietary changes.

TABLE 8.--Total liver lipid values

Diet and treatment	Values at-- 4 Weeks	8 Weeks	12 Weeks
		mg./g.	
Wheat gluten-wheat starch			
NA	102.0	71.8	47.7
A/NA	88.0	84.6	41.2
A	66.0	174.7	146.3
Wheat gluten-sucrose			
NA	98.6	65.1	46.4
A/NA	76.0	86.0	48.1
A	66.3	98.1	82.6
Casein-wheat starch			
NA	41.8		67.8
A/NA	74.9	125.1	51.3
A	63.8	209.2	267.1
Casein-sucrose			
NA	63.2	85.7	200.8
A/NA	72.4	128.8	53.9
A	96.7	166.1	152.3
Wheat gluten-wheat starch	77.5		
Casein-sucrose			
A		125.5	
Wheat gluten-wheat starch			152.3
Rat growing diet			
NA	76.3	92.4	73.0

It is evident that the quantity and type of fat and the amount of dietary cholesterol are not the only dietary components responsible for the regulation of lipid metabolism in animals and man. Carbohydrates are definitely implicated. The complex carbohydrate from wheat starch appears to produce lipid levels in blood and liver somewhat below those levels produced by refined carbohydrates (sucrose). In addition to fat, dietary cholesterol, and carbohydrate source, it has been shown that protein clearly influences the levels of the lipid parameters. These observations reappear in the tables presented. As anticipated, added dietary cholesterol increased the serum and liver lipids. Wheat gluten, when combined with sucrose, gave the lowest values in the majority of the lipid parameters. The highest levels of the lipid material being analyzed for were in the group of rats that were fed the diet containing casein and wheat starch. Wheat starch did not do this when combined with wheat gluten, nor did sucrose when combined with casein, although it was consistently higher than the wheat gluten-sucrose group. In the groups where the diets were interchanged, there appeared to be an influence of time where A-WG-WS did not decrease the values.

The present investigation calls attention to the overall problem and the complexity of the possible interactions. Although this study does not explain why wheat or wheat products are beneficial in controlling high levels of lipids, it does suggest that synergism exists among the protein, carbohydrate, and fat dietary components. Our experiments are consistent with the idea that wheat should be considered as an integral part of man's diet.

Insofar as the use of wheat is concerned, we are confronted with a problem that is not answered simply by experimentation. There is adequate evidence that cereal-based products and complex carbohydrates, in general, can influence the lipid levels in man and animals, but the extent to which this effect is altered over time is not clear. What is significant is that no data exist showing increasing serum cholesterol levels when bread or other cereal-based products are a part of the diet. Thus, the problem essentially involves a conflict: Individuals suffering from high serum cholesterol and triglyceride levels are placed on diets that specifically exclude bread and similar products, yet there is no evidence to support this course of action.

The elimination from our diet of wheat and other complex carbohydrates began sometime ago. In 1890, the ratio of complex to simplex carbohydrates was 2.9; in 1960, it was 0.9. The consumption of all carbohydrates had declined by 28 percent; the consumption of starches had declined by 59 percent; but the consumption of sucrose had declined only 25 percent (5). The differences are probably greater today.

How can the increased consumption of this worthwhile food be encouraged? For one thing, those involved in health education, in emphasizing the dangers of obesity, must be discouraged from calling for a lower intake of bread and those other "starchy foods." It is inaccurate to call a food like bread, with a protein content of 10 to 14 percent, a starchy food, with the implication that it is nothing more than a source of carbohydrate. Also, people are likely to retain throughout their lives a taste for wheat products acquired in childhood. Increased exposure of children in school feeding programs to wheat in a variety of forms--gruels, noodles, rolls, buns, biscuits, and, to an increasing extent, bulgar--may assist the child in developing better food habits. For changes to occur, the consumer must be provided with the knowledge that bread and other cereal-based products provide good nutrition, possess acceptable flavor, are economical, and--the most salient point of this discussion--do not cause high levels of cholesterol and triglycerides; hence, they do belong in our diet.

Literature Cited

(1) Ahrens, E. H., Hirsch, J., and Insell, W. Effects of dietary fats on the serum lipids of human subjects. J. Clin. Invest. 34:918. 1955.

(2) Albanese, A. A., Higgons, R. A., Lorenze, E. J., and Orto, L. A. Effect of dietary protein on blood cholesterol levels of adults. Geriatrics 14:237. 1959.

(3) Albrink, M. J., and Man, E. B. Serum triglycerides in coronary artery disease. Arch. Intern. Med. 103:4. 1959.

(4) Anderson, J. T. Dietary carbohydrate and serum triglycerides. Amer. J. Clin. Nutr. 20:168. 1967.

(5) Antar, M. A., Ohlson, M. A., and Hodges, R. E. Changes in the retail market food supplies in the United States in the last seventy years in relation to the incidence of coronary heart disease, with special reference to dietary carbohydrates and essential fatty acids. Amer. J. Clin. Nutr. 14:169. 1964.

(6) Beveridge, J. M. R., Connell, W. F., Mager, G. A., Firstbrook, J. B., and Dewolfe, M. S. Effects of certain vegetable and animal fats on plasma lipids of humans. Circulation 10:593. 1954.

(7) Brusis, O. A., and McGandy, R. B. Nutrition and man's heart and blood vessels. Fed. Proc. 30:1417. 1971.

(8) de Groot, A. P. Invloed van eiwitten op de cholesterospiegel van het bloed. Voeding 22:374. 1961.

(9) Galbraith, W. B., Conner, W. E., and Stone, D. B. Weight loss and serum changes in obese subjects given low calorie diets of varied cholesterol content. Ann. Intern. Med. 64:268. 1966.

(10) Grande, F., Anderson, J. T., and Keys, A. Effect of carbohydrates of leguminous seeds, wheat and potatoes on serum cholesterol in man. J. Nutr. 86:313. 1965.

(11) Groen, J. J., Balogh, M., Yaron, E., and Freeman, J. Influence of the nature of the fat in diets high in carbohydrate (mainly derived from bread) on the serum cholesterol. Amer. J. Clin. Nutr. 17:296. 1965.

(12) Herman, R. H., Zakim, D., and Stifel, F. B. Effect of diet on lipid metabolism in experimental animals and man. Fed. Proc. 29:1302. 1970.

(13) Hodges, R. E., and Krehl, W. A. The role of carbohydrates in lipid metabolism. Amer. J. Clin. Nutr. 17:334. 1965.

(14) Kaufmann, N. A., Poznanski, R., Blondheim, S. H., and Stein, Y. Changes in serum lipid levels of hyperlipemic patients following the feeding of starch, sucrose and glucose. Amer. J. Clin. Nutr. 18:261. 1966.

(15) Kinsell, L. W., Partridge, J. V., Boling, L. A., Margen, S., and Michaels, G. D. Dietary modification of serum cholesterol and phospholipid levels. J. Clin. Endocrinol. 12:909. 1952.

(16) Krehl, W. A., Lopez-S, A., Good, E. I., and Hodges, R. E. Some metabolic changes induced by low carbohydrate diets. Amer. J. Clin. Nutr. 20:139. 1967.

(17) Kuo, P. T., and Basset, D. R. Dietary sugar in the production of hyperglyceridemia. Ann. Intern. Med. 62:1199. 1965.

(18) Nath, N., Harper, A. E., and Elevehjem, C. A. Dietary proteins and serum cholesterol. Arch. Biochem. Biophys. 77:234. 1958.

(19) Portman, O. W., Lawry, E. Y., and Bruno, D. Effect of dietary carbohydrate on experimentally induced hypercholesteremia and hyperbetalipoproteinemia in rats. Proc. Soc. Exp. Biol. Med. 91:321. 1956.

(20) Tate, J. N., Jr., Stone, H., Mitoma, C., and Mathews, R. D. Nutritional studies with wheat. Technical Report No. 1. SRI Project BC 4757-2. 1970.

(21) Tripathy, K., Lotero, H., and Bolanos, O. Role of dietary protein upon serum cholesterol level in malnourished subjects. Amer. J. Clin. Nutr. 23:1160. 1970.

(22) Walker, G. R., Morse, E. H., and Overley, V. A. The effect of animal protein and vegetable protein diets having the same fat content on the serum lipid levels of young women. J. Nutr. 72:317. 1960.

(23) Yudkin, J. Diet and coronary thrombosis, hypothesis and fat. Lancet 2:155. 1957.

(24) Yudkin, J., and Roddy, J. Levels of dietary sucrose in patients with occlusive atherosclerotic disease. Lancet 2:6. 1964.

(25) Yudkin, J., and Morland, J. Sugar intake and myocardial infarction. Amer. J. Clin. Nutr. 20:503. 1967.

THE ROLE OF WHEAT PRODUCTS FOR FOREIGN ASSISTANCE PROGRAMS

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If we look at the role of wheat products in foreign assistance programs, we must start with wheat. Wheat grain has been a leading and basic commodity in such programs. I won't spend much time, however, on wheat other than to comment that as you all know, the P.L. 480 shipment of wheat, in Title I particularly, have been trending down over a period of time and that these have been replaced in part by commercial sales. Wheat shipments have trended down for several factors. One is that certain countries have been removed from these foreign assistance programs. Another distinct factor is the increased production brought about in Asia by the "Green Revolution." Flour is another important item in the foreign assistance programs. Flour exports have also been trending downward as foreign mills are being built. Primarily most flour exports now are under Title II or donation programs and this is apparently a downtrend that will continue into the foreseeable future.

New wheat products have come on the scene which give hope for continued and even increased wheat product exports. Bulgur began entry into the Title II programs in 1961-62 when a shipment of 590,000 hundredweight was made. The next year this amount jumped almost fivefold, and by 1963-64 through 1966-67 ran at almost a static rate of 4 million hundredweight of bulgur. Since then this has increased slowly but surely and leveled off in the last 2 or 3 years at about 5 million hundredweight. I think the breakdown of this is somewhat significant so we will take the 1970-71 totals. Title II foreign relief exports accounted for 3,994,000 hundredweight, whereas Title I commercial sales and other accounted for 1,839,000 hundredweight for a total of 5,833,000 hundredweight. Now, four-fifths of this exportation went to Asia and three-fifths of the total were used in India and Indonesia. Domestically we have seen a usage of bulgur recently in our school lunch program of 5 million pounds. Bulgur has achieved this level of sales, in my opinion, only through a concerted marketing effort and probably usage will grow or not grow greatly dependent upon the effort put behind merchandising it. I want to point out too that bulgur has a protein content of 9 percent minimum and a protein efficiency ratio (PER) as a measure of its nutritional value of 1.0 in comparison with casein at 2.5, which is the standard. Its approximate price at gulf ports is about 6 cents a pound.

In 1966 there were a couple of significant changes in P.L. 480, one of which was that emphasis was given to helping countries that demonstrated self-help programs. More important, to our thinking, was a nutrient thrust provided by the stipulation that the products in export P.L. 480 no longer had to be necessarily in surplus. Preceding that action in 1965, there were guidelines for food formulation for infants and children developed by an inter-agency government committee which indicated that a blended food product should be palatable, be low cost, have an ease of preparation, have a high nutritional value per unit of cost, and have good storage stability.

The guidelines, coupled with the change in P.L. 480, opened the door for a number of very significant products to be developed. I believe the first one in this family was CSM or corn-soy-milk. This was quickly followed by the development of wheat-soy-blend (WSB) essentially for the same end use purposes. Wheat-soy-blend is 73 percent wheat derived material, 20 percent defatted soy flour, 4 percent stabilized soy oil, and a vitamin and mineral premix. It is precooked and has a minimum protein content of 20 percent and a PER of 2.4. It is being delivered out of the gulf ports at approximately 9 cents a pound. In fiscal year 1969, WSB really made its first appearance on the market with 2.9 million pounds being shipped in export; in fiscal year 1970, 11 million pounds; and in fiscal year 1971, 33 million pounds. In 1972 it is estimated to reach 100 million pounds. Of this total, 42 percent last year went to Africa with 73 percent of that going to Nigeria in the Biafran relief program. Twenty-five percent of the total went to Latin America and 25 percent to South Asia and the Near East.

The use of WSB has been traced and much of this information reported by Frank Horan, of ADM Milling Co., recently in Miami at a Western Hemisphere Nutrition Congress. The apparent use of wheat-soy-blend is about 40 percent for preschool children, 40 percent school lunch programs, 10 percent in food-for-work programs. I don't know if you are familiar with these or not. They are public works programs in which the people who work receive part of their pay in commodities. Five percent went into institutional feedings, such as hospitals and 5 percent in a category called family rehabilitation which is a refugee program. WSB has been primarily used as a gruel, as a soup, or as a beverage. But there is indication now that it is being used in bakery products as a partial replacement of flour in cookies in school-lunch programs. As I said earlier, it is serving essentially the same users as CSM, but WSB is being used in the parts of the world where wheat is more familiar than corn flour or flavor. It has not sold itself. Shipments of WSB did not begin until people went out into the countries, worked with the voluntary agency groups and the Food-for-Peace personnel to demonstrate how WSB could be used in their existing relief and donation programs.

Blend A is another commodity which has been developed by the wheat industry and the USDA. Blend A is composed of 70 percent straight grade flour and 30 percent wheat protein concentrate. It contains roughly 13 to 14 percent protein and has PER of 1.0 compared with approximately 0.8 for wheat flour. In developing countries of the Middle East and South Asia, the principal use for this product was designated to be in non-leavened breads, such as the chapati. Storage stability problems have caused a great deal of concern with this product. There has been a fine research effort at the Western Regional Research Laboratory to overcome this stability problem which takes its principle form in the development of a bitter flavor. Specifications have been redrafted to try to overcome this and the first purchase of Blend A of any significant quantity was made this last June when 500,000 pounds was purchased. It delivered at the port for about 6-1/2 cents per pound.

We are now entering an era of second generation products. This past summer three shipments were made of lysine fortified bulgur. There was a total of 37-1/2 million pounds shipped from July to September to India. There was 0.1 percent lysine added to the food products. The protein content is 10.5 percent and the PER was raised to 1.6-1.8. Lysine fortified bulgur shipped out of the gulf ports for 6-1/4 cents per pound. This apparently is being replaced, if you look at the current shipments, by soy fortified bulgur which contains 1 percent soy grits, has 17.3 percent protein and has a PER of 2.0. In the last 3 months there have been 61.7 million pounds of this product shipped to India apparently for their BalAhar or weaning food program. This is delivered at the gulf ports at 6.06 cents per pound.

A new WSB has just been purchased but not shipped. This is a sweetened and flavored wheat-soy-blend which has 15 percent sugar and vanilla flavoring added. A sweetened and flavored corn-soy-milk blend is also being shipped. Sweetened and flavored WSB has a wheat portion of 55.7 percent, 22 percent defatted soy flour, 4.5 percent soy oil, 2.65 percent vitamins and minerals, 0.15 percent vanilla flavoring, and 15 percent sugar. It still maintains the protein minimum of 20 percent and the values of the PER should not be too much different from regular wheat-soy-blend. This sells for shipment at 10 cents per pound at the gulf ports. The cost of sweetened and flavored CSM was 11.5 cents a pound.

Now, this family of products, as you can see, is designed for simple foods, simple preparation, high nutritional value at low cost. There is a gap in this family of products now offered which could be filled by high protein bread flour. There has been proposed a specification for a soy fortified bread flour product for these purchasing programs which is currently being designated as Blend K, which contains 89 percent bread wheat flour, roughly 10.7 percent defatted soy flour, 0.4 percent emulsifier, plus a vitamin and mineral premix. It would have roughly 11.5 to 12 percent protein in the final consumed product and a PER of approximately 2.0. The usage of this product has been demonstrated in foreign countries to be acceptable in bread, cookies, other baked foods, and in noodles. We think the users would be largely the school lunch programs, food-for-work programs, and institutional feeding programs. Many of the large cities and not too large cities in a great number of countries are now going to school lunch programs with contract simplified food preparation such as baking. Alternatives are needed to gruels as diet change. Bread is being used now in these programs, and if it is being nutritionally improved it is usually with the addition of milk solids. Nonfat milk solids are expensive and present a great difficulty to the voluntary agency and Food-for-Peace people in controlling their usage. Since milk solids are a commodity of some value, there is speculation that all of the milk does not go into this bread. The level of addition is difficult to measure and thus control. We think a prepackaged complete flour product delivered from the United States will assist this greatly, assuring nutritional value to the final consumer without increasing the cost.

High protein bread offers a real opportunity for the wheat and milling industry to introduce wheat foods into the diet of children who have grown up on diets of rice or corn, in Asia or South America, and to introduce them in a way in which wheat food products would be identified as nutritious at an early age. We certainly think that the long range exports of wheat and flour from the United States would benefit as much from this educational process at the school-lunch age in the developing countries as any merchandising program that could be undertaken.

In this paper we have reviewed the family of wheat products that are presently in shipment or which we would hope will soon be in shipment. I think that this family, which undoubtedly will be altered and augmented in the future, does give the potential of the complete range of wheat based foods for all of the target population groups in the less developed countries. These products do provide a range of food forms which may become the backbone of their diets.

UPGRADING THE NUTRITIONAL VALUE OF WHEAT MILLING FRACTIONS

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Seeds consist of a dormant baby plant (the germ), plus a food supply for the young plant (the endosperm in the case of wheat). In addition, seeds have defense mechanisms which help to prevent their destruction by hostile environmental factors including hungry animals and people. Thus, many plants contain extremely poisonous materials and are shunned by man and animal as food sources. Early man found some plants which could be eaten and which were highly nutritious and these included the cereal grains, especially wheat. Wheat and most grasses are low in deleterious compounds and survived in preagriculture days largely on the basis of extremely high growth rates and seed productivity. Another survival character of cereal seeds is the tough outer layers that protect it from too rapid water absorption, microorganisms, and physical damage.

When we mill wheat grain we take its stored food supply and make it into flour. In the process, we concentrate the seeds' defense mechanisms in the millfeed fractions. Thus it is not surprising that we have encountered problems of poor digestibility in animals when feeding millfeeds.

This presentation will cover the present status and limitations in mill byproducts as feeds and attempt to improve the nutritive value by physical methods, enzymatic methods, and chemical methods. Most of the research on this aspect of wheat millfeeds has been in poultry nutrition.

The Millers' National Federation has supported a great deal of the research carried out at Guelph and our Laboratory.

In 1965 Cave et al. (5) showed that for poultry, bran supplemented only with a vitamin-mineral mix was unable to sustain life, and shorts supported only a poor rate of growth. However, growth and feed efficiency of chicks were good when they were fed either shorts or germ diluted with 50 percent of a corn-soybean meal ration. High pressure steam-pelleting of rations containing 50 percent of wheat millfeed improved growth and feed efficiency. The level of feed intake was increased for all rations and the metabolizable energy values for bran, shorts, and wheat germ meal were increased substantially. This records the first good improvement in nutritional value of wheat millfeeds and some figures are shown in table 1. The metabolizable energy figures here seem extraordinarily high; but, since we are concerned only with the actual improvements, we will not go further into this. However, of importance in another report by the Guelph group (2) steam pelleting reduced the metabolizable energy value of middlings and shorts. These same workers also reported a decrease in biological availability of bran phosphorus after pelleting (20).

TABLE 1.--Weight gains, feed: Gain ratios of chicks fed steam-pelleted rations containing 50 percent wheat millfeed /M.E. Values for the Millfeeds (1)/

Wheat millfeed	Weight gain	Feed: gain	M.E.	M.E. increase
	Grams		Kcal./kg.	Percent
Mash:				
Bran	98	4.17	2,000	---
Shorts	101	3.44	2,250	---
Midds	123	2.91	3,480	---
WGM	81	3.64	2,790	---
Pellets:				
Bran	149	3.11	2,600	(30)
Shorts	163	2.88	2,640	(17)
Midds	176	2.31	3,540	(1.7)
WGM	124	2.00	3,210	(15)

Steam-pelleting rations is extensively used in the poultry feed industry. The advantages and disadvantages of pelleted feeds for various classes of poultry have been thoroughly reviewed by Calet (3). The general improvement in performance of meat production stock with pelleted diets has been attributed to a combination of factors, including lowered energy expenditure in eating, a denser diet and greater feed consumption, chemical changes in the ration itself, and reduced feed wastage. For example, nitrogen digestibility in bran increased by 20 percent for chicks (4) after steam-pelleting. Although it has been generally established that pelleting increases the nutritive value of wheat millfeeds, a degree of caution is in order. Results can be inconsistent. For example, when layers were fed corn-soybean meal or wheat-soybean meal containing 15 or 30 percent bran or shorts, either as mash or crumbled pellets (16), the mash diets resulted in significantly more eggs per bird. It is likely that product variability is caused by differences in holding times and die thickness and design. Figure 1 shows a plot of in vitro protein digestibility of pellets manufactured from bran in a mill with varying die size and moisture content. This indicates for optimizing protein digestibility, pelleting with a 1/4 inch diameter, 1-1/2 inch thick die size, and 15 percent moisture is required.

In the steam-pelleted or autoclaved millfeeds, increases in metabolizable energy and feed efficiency are almost invariably accompanied by increases in fat and protein digestibility. To gain improvements in nutritive value, it is imperative that fat and protein be more fully utilized.

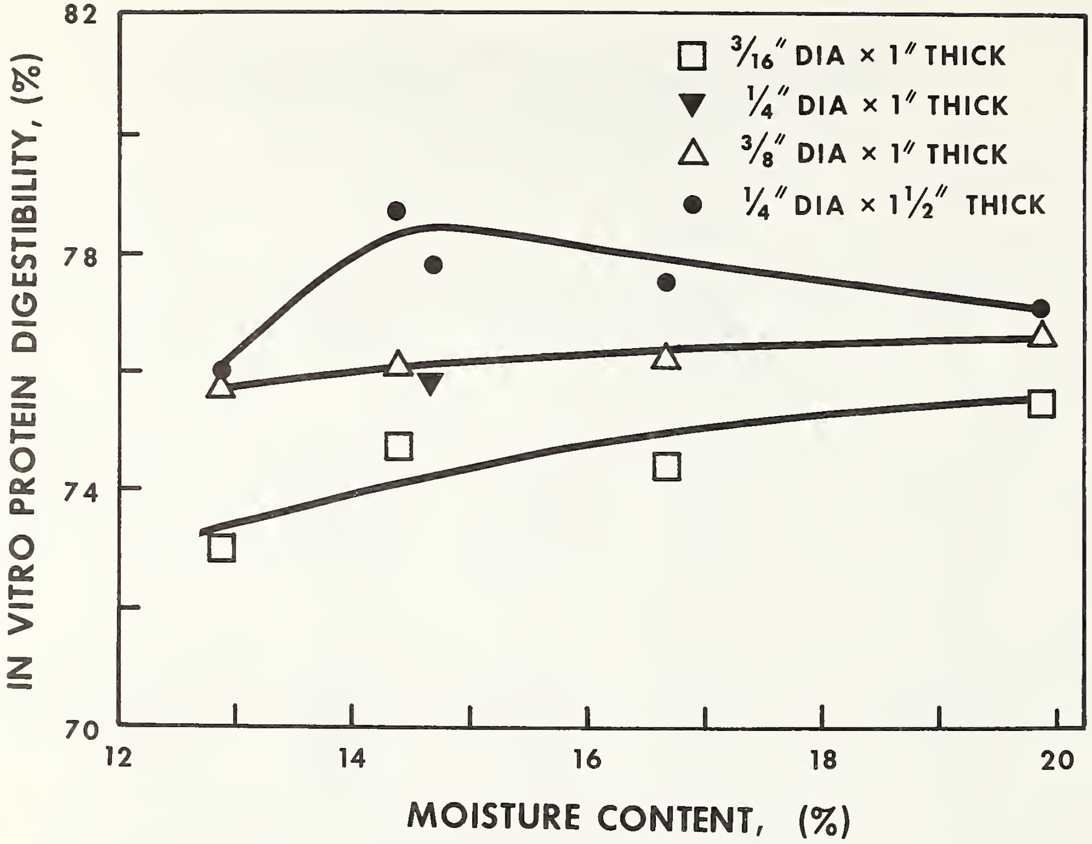

Figure 1.--Protein digestibility of bran pellets.

Numerous studies have been made on protein quality and availability in wheat millfeeds, and how these factors can be improved. Relative to most other grains, wheat millfeeds contain a high level of protein. Data by Miladi et al. (11) showed that millfeeds have a much superior protein quality than that of flours or whole wheat (table 2). These workers also showed that lysine supplementation improved the protein quality of all millfeed proteins with the exception of germ where no effect was observed. Even though the protein of millfeeds is of relatively high content and quality, the actual biological availability is low in some cases, and often very low in bran. Table 3 lists nitrogen digestibility figures for millfeeds as determined by different research groups. The variation in protein digestibility, especially for bran and shorts, is extremely large. This is probably due to the amount of endosperm carried through with the branny fraction during milling but also due to variation in age and source of the millfeeds. These serious differences present a problem when formulating rations. It is essential that work must be carried out to find methods to improve these values where possible or to produce a more uniform product. Saunders et al. (19) indicated that increased nutrient availability can be derived from improved digestibility of the aleurone layer content. It appears that a rupture in the aleurone cell wall is necessary for maximum digestion of the rich cell contents, presumably by allowing better access by digestive enzymes. Pelleting actually causes rupturing of aleurone cell walls (19). Other milling procedures have been used to process bran and shorts with the idea in mind of improving the digestibility of fat and protein. Kertesz et al. (8) by use of in vitro measurements of protein digestibility have shown that certain milling procedures may be advantageous. Table 4 shows the effect of roller milling bran. An increase in protein digestibility is apparent. Table 5 shows measurement of protein digestibilities in different brans before and after ball-milling. Again, an increase in digestible protein is apparent. Of interest, Ranhotra et al. (17) recently showed a 9 percent increase in nitrogen retention when reground shorts versus regular shorts were fed to rats. Changing the particle size of millfeeds also seems to lead to better fat availability. Table 6 shows ether-extractable fats in different sized bran particles before and after ball-milling. This experiment suggests considerable scope for improvement in fat digestibilities by appropriate processing of bran.

TABLE 2.--Relative nutritive value[1] of wheat millfeed protein with and without lysine supplement (8)

Wheat sample	Relative nutritive value	
	Unsupplemented	With lysine supplement
Germ	80 ± 5	80 ± 3
Shorts flour[2]	72 ± 4	75 ± 3
Red dog	60 ± 3	68 ± 3
Shorts	55 ± 3	65 ± 3
Bran	49 ± 3	56 ± 3
Whole wheat	36 ± 3	57 ± 3
Patent flour	23 ± 4	51 ± 3
Clear flour	25 ± 3	50 ± 3

[1] Relative nutritive value is expressed as percentage of the nutritive value of lactalbumin.

[2] Wheat protein concentrate prepared by milling and screening shorts.

TABLE 3.--Nitrogen digestibility of various wheat millfeeds

Wheat samples	Bran	Shorts	Red dog	Germ
	Percent	Percent	Percent	Percent
HRW[1/]:				
9001	60.8	72.2	82.9	84.3
9002	61.3	74.1	86.2	79.2
9008	61.6	73.5	85.4	80.7
9007	60.7	72.2	81.0	82.2
9010	60.3	73.6	87.5	82.1
HRS[1/]				
9009	52.5	70.0	84.7	85.6
9003	64.5	75.9	84.1	84.8
White[1/]				
9005	61.2	70.0	80.0	80.1
SRW[1/]				
9006	59.6	68.4	85.9	81.9
HRS[2/]	73.0	77.4	84.6	86.7
Canadian hard wheat[3/]	72.8-76.8	81.5-85.5	---	---
Overall range	52.5-76.8	68.4-85.5	80.0-87.5	79.5-86.7

[1/] Summers, Moran, and Pepper (9).

[2/] Saunders and Kohler (10).

[3/] Olsen, Simmers, and Slinger (11).

TABLE 4.--In vitro protein digestibility of Ross-milled wheat bran (13)

Roller separation (Inches)	Times milled	Protein digestibility
		Percent
0.004	1	70.6
0.002	1	72.5
0.000	1	82.8
0.000	2	85.5
0.000	3	85.6

TABLE 5.--In vitro protein digestibility of wheat brans before and after ball-milling (13)

Bran	Protein digestibility		Increase
	Normal	After ball-milling	
	Percent	Percent	Percent
HRS	70.6	84.7	20
HRS	63.8	85.5	34
HRS	68.1	85.5	26
HRW	62.0	84.9	37
HRW	63.6	85.5	34
HRW	65.4	83.9	28
SRW	63.1	83.5	32
SWW	65.5	90.1	38

TABLE 6.--Ether extractable fats in wheat bran fractions before and after ball-milling (13)

Particle size (mesh)	Fats before ball-milling	Fats after ball-milling	Increase
	Percent	Percent	Percent
10	3.24	5.59	72.5
18	3.70	5.79	56.5
28	4.03	5.68	40.9
48	5.08	4.70	12.2
80	5.21	5.32	2.1
80	2.81	2.91	3.5

Summers and coworkers at Guelph have published considerable data on amino acid availability for wheat millfeeds using rats or chicks (12,14,15). Table 7 shows summarized data obtained with rats, and again, note the low nitrogen digestibility. The absorption of individual amino acids followed the same trend. Table 8 shows the effect of supplementing bran diets with amino acids and comparison with a soybean meal ration. In diet 8 bran feed has been supplemented to a point where it compares favorably with a soybean meal ration (diet 1). Although this does not show a method of improving millfeeds per se, it does illustrate how the nutritive value of millfeeds can be improved by supplementation. Similar results have been obtained with shorts and middlings. It is evident that if the protein of wheat millfeed is properly supplemented to correct known amino acid deficiencies, this protein can support weight gain and feed utilization equal to that of soybean meal protein.

TABLE 7.--Wheat gain, feed efficiency, NPU and nitrogen digestibility in wheat millfeeds (11)

Source of protein	Wt. gain Rat/wk.	Feed:gain	NPU	Nitrogen digestibility
	Grams		Percent	
Bran	11.5	6.26	43.2-	76.8
Shorts	24.2	3.41	59.0	81.5
Midds	20.8	3.87	57.9	82.0

TABLE 8.--Effect of supplementing bran diets with amino acids (15)

Diet No.	Treatment	Wt. gain	Feed consumed	Feed:gain
		Grams	Grams	
1	SBM + 0.15 percent methionine	30.1 ± 1.02	88	2.92
2	Bran 1 + glutamic acid	8.4 ± 0.99	66	7.86
3	Bran 1 + threonine + methionine + lysine + isoleucine	19.4 ± 2.15	71	3.67
4	Diet 3 + valine	20.4 ± 2.16	70	3.43
5	Diet 4 + leucine	26.1 ± 2.52	84	3.24
6	Diet 5 + histidine	23.7 ± 2.58	75	3.16
7	Diet 6 + phenylalanine	24.4 ± 1.91	78	3.19
8	Diet 7 + tryptophan	27.8 ± 1.43	82	2.91

Treatment with water and fungal enzymes of Northwest wheat and milling fractions flour, bran, germ, shorts, wheat millfeed, and middlings has been carried out (10). Water treatment improved the use of all milling fractions except flour. Additions of fungal enzymes improved the growth of only those chicks fed bran or wheat millfeed.

Enzymatic degradation of bran using cellulolytic and proteolytic hydrolyses has been studied by Neudoerffer and Smith (13). The nutritional value of bran for the rat was significantly improved. Protein digestibility and metabolizable energy were both increased, the latter resulting partly from solubilized cellulosic material. Saunders et al. (18) have processed bran with different commercial cellulase-type enzymes. Table 9 shows change occurring in in vitro protein digestibility. In vitro protein digestibility in the untreated bran was 70 percent. Good increases are apparent. In addition to increases in protein digestibility, cellulosic material has been converted to glucose, digestible by monogastric animals. Figure 2 shows a quantitative column fractionation of the sugars extracted from unprocessed bran and from treated bran. A large increase in glucose is apparent after processing. The entity in the bran undergoing attack by the cellulase enzymes is the aleurone cell wall. Table 10 shows the result of a caloric feeding trial with rats. An increase of about 25 percent has been recorded in both weight gain and bran dry matter digestibility.

These nutritive improvements in bran, which undoubtedly can be registered in the other high fiber millfeed fractions, are a good improvement. In addition, there may be an unidentified growth factor for chicks produced during the process. Ely et al. (7) have developed a process for increasing the growth response and feed efficiency of poultry by introducing into a feed, which is fed to poultry, a supplement comprising a mixture of (a) a material prepared by fermenting wheat bran under aerobic

TABLE 9.--In vitro protein digestibility of wheat bran after treatment with enzymes (19)

Enzyme pretreatment	Protein digestibility after[1]:					
	1 day at 70° F.	2 days at 70° F.	1 day at 95° F.	2 days at 95° F.	1 day at 104° F.	2 days at 104° F.
1 Percent pectinol 41-P concentrate	80.6	84.9	84.0	---	85.5	86.7
2.5 Percent pectinol 41-P concentrate	86.2	87.1	85.7	---	88.1	89.3
5 Percent pectinol 41-P concentrate	86.7	88.9	87.1	---	89.3	90.7
1 Percent cellulase 36 concentrate	78.9	80.7	78.1	79.7	79.6	84.2
2.5 Percent cellulase 36 concentrate	81.9	84.0	82.8	85.2	88.1	89.9
5 Percent cellulase 36 concentrate	87.1	86.4	86.9	88.2	90.7	93.1

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[1] Protein digestibility in untreated bran, 69.0 percent.

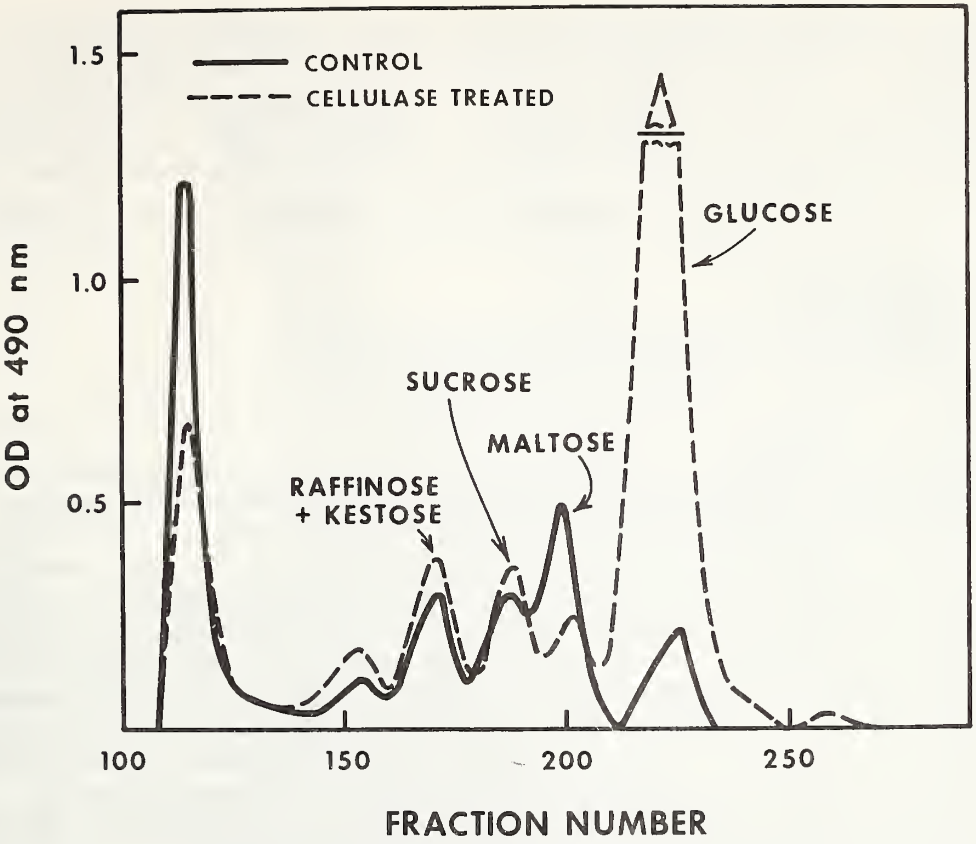

Figure 2.--Fractionation of sugars extracted from treated and untreated brans.

TABLE 10.--Weight gain by rats fed enzymatically processed wheat bran; and changes in bran DMD (19)

Supplement	Corrected net wt. gain (5 rats, 7 days)	Bran DMD
		Percent
Basal control	(0)	--
Basal + bran	+ 49	37
Basal + pectinol control bran	+ 53	42
Basal + pectinol treated bran	+ 65	52

conditions using *Aspergillus oryzae* and (b) a material prepared by fermenting wet wheat bran under aerobic conditions using *Bacillus subtilis*. Improvements up to 22 percent over controls were reported at very low supplemental levels of about 0.4 percent, and is attributed to an unidentified growth factor. This is illustrated in table 11. Although these methods of processing are at present uneconomic, this work may perhaps hint at a direction for research aimed at improving the nutritive value of millfeeds for poultry.

TABLE 11.--Feeding rations supplemented with fermented bran (20)

Experiment	Fermented bran added	Improvement in weight gain	Improvement in feed gain
	Percent	Percent	Percent
Basal + A. oryzae/bran	0.35	11.4	2.5
Basal + B. subtilis/bran	0.35	12.0	4.1
Basal + A. oryzae + B. subtilis/brans	0.18 + 0.18	22.0	6.7

Mild acid treatment of wheat has been shown to improve growth when fed to chicks (1). It will be of interest to see if millfeeds respond in the same manner. In this respect our laboratory has treated bran with various acids or alkalis and looked at the products by in vitro procedures. As can be seen in table 12 a good increase in protein available for digestion by proteolytic enzyme was recorded in bran treated with either ammonia or sodium hydroxide. However, when these products were fed to rats in a standard PER assay growth was less than the control. This we interpret as being due to destruction of a limiting amino acid, probably cystine. This problem still remains to be solved. In addition, in our laboratory we have achieved good increases in total digestible nutrients (TDN) with ammoniated or alkali-treated fibrous materials when fed to ruminants, and hence are quite confident that similarly treated millfeeds will show nutritive improvement when fed to ruminants.

Autoclaving of wheat germ has been shown to have some beneficial effect. Cave et al. (4) have shown that when a ration containing 33 percent autoclaved wheat germ meal was fed to growing chicks, weight gain, feed efficiency, metabolizable energy, and fat digestibility increased compared with raw wheat germ meal. This effect is destruction by autoclaving of a thermolabile growth inhibitor. The time of autoclaving is critical since prolonged heating seriously impaired chick performance. Freezing has been shown to have a beneficial effect on the metabolizable energy of whole wheat (6) for chicks; it will be of interest to see if millfeeds respond in the same manner.

While it is generally believed that swine metabolize about the same amount of energy of feedstuffs as do poultry, this is probably a misconception where wheat millfeeds are concerned. It is apparent that the pig metabolizes much more of the energy in bran than does the chick. Young (21) has recently shown that bran yields a metabolizable energy value 59 percent higher for pigs than that for poultry, and shorts yields a figure 62 percent higher. Table 13 lists various digestible energy and metabolizable energy values of bran and shorts for different animals. Coupled with the fact that virtually no reports have appeared on attempts to improve the nutritive value of millfeeds in animal nutrition other than poultry, this table dramatizes the point that upgrading the nutritional value of wheat milling fractions is almost invariably concerned with the poultry feed business. Kohler et al. (9) have already demonstrated by computer evaluation that it will be possible to increase the use of millfeeds in poultry feeds only if the biological availability of nutrients can be increased. Continued research is, therefore, needed to ensure maximum utilization of these valuable companion products of flour milling.

TABLE 12.--Protein in wheat bran solubilized after pronase digestion (19)

Bran treatment	Protein solubilized	Increase in solubilized protein
	Percent	Percent
Control	72.2	---
Bran + 2.5 percent NH_4OH	79.9	10.7
Bran + 2.5 percent NaOH	85.1	17.9
Bran + 2.5 percent H_3PO_4	74.8	3.9
Bran + 2.5 percent HCl	74.8	3.6

TABLE 13.--Metabolizable energy values of millfeeds for different animals (24)

Animal	Bran	Shorts	Middlings
	Kcal./kg.		
Cattle	2,530	3,109	3,001
Swine	2,608	3,235	2,883
Sheep	2,386	3,073	2,712
Horse	3,290	---	---
Chickens	1,288	2,940	2,009

Literature Cited

(1) Adams, O. L., and Naber, E. C. Effect of physical and chemical treatment of grains on growth of and feed utilization by the chick. Poultry Sci. 48:922. 1969.

(2) Bayley, H. S., Summers, J. D., and Slinger, S. J. Effect of heat-treatment on the metabolizable energy value of wheat germ meal and other wheat milling by-products. Cereal Chem. 45:557. 1968.

(3) Calet, C. The relative value of pellets versus mash and grain in poultry nutrition. World's Poultry Sci. J. 21:23. 1965.

(4) Cave, N. A. G., Slinger, S. J., and Summers, J. D. Significance of processing wheat-germ meal for growing chicks. Canad. J. Animal Sci. 48:199. 1968.

(5) Cave, N. A. G., Slinger, S. J., Summers, J. D., and Ashton, G. C. The nutritional value of wheat milling by-products for the growing chick. I. Availability of energy. Cereal Chem. 42:523. 1965.

(6) El-Lakany, S., Biely, J., and March, B. E. Improved nutrient utilization from wheat subjected to autoclaving and freezing. Cereal Chem. 46:301. 1969.

(7) Ely, C. M., DeLuca, A. P., and Andriuli, F. U.S. Patent 3,151,983; October 6, 1964; assigned to Nopco Chemical Co.

(8) Kertesz, D. J., Saunders, R. M., and Kohler, G. O. Increased protein availability in wheat bran. AACC meeting, Minneapolis, Minn. October 1970.

(9) Kohler, G. O., Saunders, R. M., Kuzmicky, D. D., and Enochian, R. V. Biological availability of nutrients and computer evaluation of millfeeds. Feedstuffs 42:41. 1970.

(10) Leong, K. C., Jensen, L. S., and McGinnis, J. Improvement of the feeding value of wheat fractions for poultry. Poultry Sci. 39:1269. 1960.

(11) Miladi, S., Hegsted, D. M., Saunders, R. M., and Kohler, G. O. The relative nutritive value, amino acid content, and digestibility of the proteins of wheat mill fractions. Cereal Chem. 49:119. 1972.

(12) Moran, E. T., Summers, J. D., and Pepper, W. F. Nutritional evaluation of selected milling fractions from wheats of different type and geographical area of production: First three limiting essential amino acids for the chick and performance under dietary conditions calculated adequate. Poultry Sci. 49:371. 1970.

(13) Neudoerffer, T. S., and Smith, R. E. Enzymic degradation of wheat bran to improve its nutritional value for monogastrics. Canad. J. Animal Sci. 49:205. 1969.

(14) Olsen, E. M., Summers, J. D., and Slinger, S. J. Evaluation of protein quality in wheat by-products: Digestibility of protein and absorption of amino acids by the rat. Canad. J. Animal Sci. 48:215. 1968.

(15) Olsen, E. M., Summers, J. D., and Slinger, S. J. Biological availability of amino acids in wheat by-products. Canad. J. Animal Sci. 48:221. 1968.

(16) Pepper, W. F., Summers, J. D., Slinger, S. J., and Ashton, G. C. Effect of steam pelleting on the performance of hens fed various laying diets. Canad. J. Animal Sci. 48:229. 1968.

(17) Ranhotra, G. S., Hepburn, F. N., and Bradley, W. B. Effect of fiber on availability of protein from wheat shorts. Cereal Chem. 48:9. 1971.

(18) Saunders, R. M., Connor, M. A., Edwards, R. H., and Kohler, G. O. Cellulase treatment of wheat bran. AACC meeting, Dallas, Texas, October 1971.

(19) Saunders, R. M., Walker, H. G., Jr., and Kohler, G. O. Aleurone cells and the digestibility of wheat millfeeds. Poultry Sci. 48:1497. 1969.

(20) Summers, J. D., Pepper, W. F., Bayley, H. S., and Slinger, S. J. The effect of steam pelleting on the utilization of phosphorous in wheat bran. Poultry Sci. 47:1397. 1968.

(21) Young, L. G. Feedstuffs. p . 4 (March 27, 1971).

FEEDING WHEAT TO BEEF CATTLE

By John R. Brethour, Fort Hays Experiment Station, Kansas State University

The proportion of meat and livestock products in the American diet is steadily increasing while foods made from wheat are declining. This suggests we use wheat in livestock feeds--to benefit the economy of wheat producing communities by converting wheat to a more marketable product near (and often on) the farms where it is grown.

Wheat appears to have advantages, unique among grains, in livestock rations, particularly those for beef cattle. In many industrial applications, grains may be freely substituted for each other, the cheapest being used. Wheat used as livestock feed would add to its demand elasticity.

Digestion and use of energy by ruminants is more complex than by simple-stomached animals. Wheat carbohydrate (starch) seems to be metabolized in the ruminant by slightly different and more efficient pathways than are energy components of other grains. That may explain why beef cattle seem to respond more than other species to wheat. Wheat can be substituted into beef cattle rations at a substantial price saving if proper nutrition and seasonal availability are considered. The price feeders are willing to pay for wheat already dictates its market value quite often. Therefore, it is important to wheat growers that feeders understand the extra nutritional values of wheat.

It is not easy to know when wheat is competitively priced with other feed grains, because wheat's relative value depends on the kind of animal being fed, and (at least with beef cattle) on energy content of the ration, wheat type and variety, and management practices.

Most beef cattle nutritionists use net energy to evaluate feeds. It seems to express combined gain, feed efficiency, and carcass quality more accurately than does total digestible nutrients (TDN). It is especially important that accurate net energy values be available for wheat because such values are used daily in hundreds of least-cost decisions to accept or reject wheat in livestock rations.

Current National Research Council net energy estimates for wheat are estimated from TDN values. In Fort Hays tests the TDN content of wheat was measured as 88 percent, compared with 91 percent for corn. However, in our performance trials with beef animals, net energy of wheat often substantially exceeded that of corn (table 1).

TABLE 1.--Estimates of NE_m and NE_p (Mcal./kg.) of wheat[1]

Date of trial	Grain	NE_m	NE_p
Values published by National Research Council, 1970			
	Rolled corn	2.28	1.48
	Rolled milo	1.85	1.23
	Rolled wheat	2.15	1.42
Strong gluten, HRW wheats in finishing rations			
Winter 69-70	50 Percent Golden 50	2.34	1.51
Summer 1970	50 Percent Scout	2.86	1.68
Summer 1970	50 Percent Golden 50	2.50	1.57
Summer 1970	100 Percent Scout	2.61	1.61
Winter 70-71	100 Percent Scout	2.34	1.50
Winter 70-71	100 Percent Golden 50	2.19	1.44
Summer 1971	50 Percent Scout (roasted)	2.44	1.55
Summer 1971	100 Percent Scout (roasted)	2.52	1.58
Summer 1971	50 Percent Scout	2.44	1.55
Summer 1971	100 Percent Scout	2.24	1.46
Summer 1971	50 Percent Scout	2.16	1.44
Summer 1971	100 Percent Scout	2.24	1.46
Summer 1971	100 Percent Scout	2.32	1.50
Fall 1971	100 Percent Eagle	2.25	1.46
		2.38	1.52
Soft wheat types in finishing rations			
Summer 1970	50 Percent Stadler (SRW)	2.30	1.49
Summer 1970	50 Percent Gaines (SWW)	2.27	1.47
Winter 70-71	100 Percent Gaines (SWW)	2.39	1.52
Summer 1971	50 Percent Arthur (SRW)	2.30	1.49
Summer 1971	100 Percent Arthur (SRW)	2.10	1.39
		2.27	1.47
Weak gluten wheats in finishing rations			
Winter 69-70	50 Percent Red Chief	2.01	1.34
Fall 1971	100 Percent K14042 (Exptl)	2.01	1.34
		2.01	1.34
Strong gluten, HRW wheats in all-concentrate rations			
Summer 1965	50 Percent Bison	1.78	1.18
Winter 65-66	50 Percent Bison	1.71	1.13
Winter 65-66	50 Percent Bison	2.15	1.41
Summer 1966	50 Percent Bison	1.76	1.16
Summer 1966	50 Percent Bison	1.80	1.20
		1.84	1.22
Wheat in high-roughage (72-77 percent), growing rations			
Winter 69-70	Scout (CSM)	2.32	1.50
Winter 69-70	Scout (urea)	2.30	1.49
Winter 69-70	Scout (Biuret)	2.69	1.64
Winter 70-71	Scout (CSM)	2.75	1.66
Winter 70-71	Scout (urea)	3.66	1.86
Winter 70-71	Gaines (CSM)	2.84	1.69
		2.70	1.64

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[1] Calculated by difference from a rolled milo control ration using relative gain, weight, and intake (Lofgreen, G. P. Wheat in Livestock and Poultry Feeds Int. Symp. Proc. 1970).

Our estimated net energy values of strong gluten HRW wheats are 7 percent higher than the National Research Council values. Net energy values for soft wheats and weak gluten wheats are lower than for wheats with strong milling qualities. Tables 2, 3, and 4 show results of growth and digestion trials comparing wheat varieties. Both gain and efficiency were greater with hard than with soft wheats (table 2). Digestibilities of the four different wheats appeared to be essentially the same (table 3). Although differences in nitrogen retention were observed, they do not easily explain performance differences.

TABLE 2.--Comparison of four wheat varieties in steer finishing rations. 128-day steer performance.

Item	Milo	Stadler SRW	Gaines SWW	Scout HRW	Golden 50 HRW
	kg.				
Average daily intake					
No fat	11.5	9.7	9.4	9.6	10.1
Fat[1]	10.9	9.4	9.2	9.5	9.7
Average daily gain[2]					
No fat	1.21	1.17	1.08	1.28	1.27
Fat	1.27	1.11	1.32	1.21	1.23
Average kg. feed per kg. gain					
No fat	9.48	8.42	8.57	7.65	8.01
Fat	8.58	8.45	7.08	7.89	7.94

[1] 0.45 kg. fat and 0.11 kg. CSM last 54 days.

[2] Least significant difference (LSD): $P<0.05$, 0.13.

TABLE 3.--Ration digestibility and nitrogen balance of wheat varieties when fed as 100 percent of grain

Item	Milo No. 3	Stadler No. 3	Gaines No. 4	Scout No. 4	Golden 50 No. 3	LSD P<0.10
Apparent digestibility, percent:						
Ash	13	40	42	47	40	22
Crude protein	60	78	78	77	82	6
Ether extract	77	69	73	74	72	2
Crude fiber	43	33	36	48	45	14
NFE	80	90	88	88	90	4
Dry matter	73	83	81	83	84	5
Daily nitrogen balance:						
Retention, g.	11	31	35	20	23	10
Percent of intake	8	23	26	15	16	6
Percent of absorbed	15	30	33	19	19	9

Table 4 compares strong and weak gluten wheats. Crude protein contents of milo, KS14042, and Eagle were 10, 17, and 14 percent, respectively. However, as in all wheat feeding tests at Fort Hays, rations were isonitrogenous. Nutritive value of the stronger gluten wheat appeared to be higher even though its protein percentage was lower. Gluten has been blamed for decreased intake of wheat fed to cattle. However, we found no difference in consumption of strong and weak gluten wheats or in carcass quality (table 4).

The relative value of wheat was less in all-concentrate rations than in high-roughage rations. Wheat's economic value has been consistently high in high-roughage rations. Results typical of several tests are shown in table 5 and indicate a pound of wheat may sometimes be worth 150 to 190 percent as much as a pound of rolled milo. An apparent trend--though not statistically significant--suggests that nonprotein nitrogen use is improved when wheat is fed. Beef feeders in other countries tend to use high-roughage rations. Making them aware of wheat's value in such rations should provide an attractive outlet for surplus wheat.

TABLE 4.--Comparison of strong and weak gluten wheats in steer finishing rations July 6, 1971, to October 24, 1971--111 days

Item	Milo 10[1]	K14042 Weak gluten 10[1]	Eagle Strong gluten 10[1]
Average daily gain, kg.	1.45	1.36	1.45
Average daily intake, kg.	12.1	10.8	10.9
Average kg. feed/kg. gain	8.40	7.99	7.56
Average feed cost per 100 lb. gain	$17.67	$16.62	$16.05
Estimated net energy values:	Milo	Wheat	Wheat
NE_m, Mcal./kg. dry matter	1.85	2.01	2.25
NE_p, Mcal./kg. dry matter	1.23	1.34	1.46
Kg. milo replaced by 1 kg. wheat	---	1.10	1.20
Value of wheat relative to milo at $2.00/cwt., $/bu.	---	$1.40	$1.49
Carcass data:			
Average dressing percent	63.4	63.7	64.0
Average cutability grade	3.54	2.77	3.13
Carcass grades:			
Prime, percent	20		10
Choice, percent	60	80	70
Good, percent	20	20	20

[1] Number of head.

Net energy values only indirectly consider differences in protein. The Fort Hays tests show that wheat protein is equal to or superior to other proteins in beef cattle rations. However, we have never been able to explain differences in responses to wheat by differences in protein content. Although high protein wheats are apparently desirable for cattle rations, protein level and quality are much more important in human nutrition. Since ruminants can use nonprotein-nitrogen, beef cattle feeders probably should not pay much premium for high protein wheat.

TABLE 5.--Wheat in high-silage growing rations--175-day performance

Item	Milo urea[1] 16[2]	Wheat urea[1] 15[2]	Milo CSM[1] 16[2]	Wheat CSM[1] 15[2]
Average air dry intake, kg.	8.57	8.66	8.89	8.85
Average daily gain[3], kg.	0.81	0.97	0.89	0.98
Average kg. feed per kg. gain	10.55	9.09	9.89	9.02
Average feed cost/cwt. gain	$18.68	$16.31	$19.27	$17.82
Estimated wheat net energy values:				
NE_m, Mcal./kg. dry matter	---	3.66	---	2.75
NE_p, Mcal./kg. dry matter	---	1.86	---	1.66
Kg. milo replaced by 1 kg. wheat	---	1.67	---	1.40
Value of wheat relative to milo at $2.00/cwt., $/bu.	---	$2.30	---	$1.93

[1] Nitrogen source.

[2] Number of head.

[3] LSD: $P<0.05$, 0.075.

Wheat contains less fat than other grains. However, we have observed a significant response to added dietary fat only with Gaines wheat (table 2). There has been little advantage to steam flaking, micronizing, or extruding wheat. Results at Hays with roasting wheat are inconclusive. Reconstituting and ensiling high moisture wheat has not been beneficial. Whole wheat can be fed but it is inefficiently used. Grinding and then pelleting wheat has been unsatisfactory. In a recent Oklahoma study, rolling appeared to be superior to fine grinding. Dry rolling appears to be the most satisfactory way to process wheat.

It has been customary to limit wheat to 50 percent of the grain in a cattle fattening ration. At higher percentages feed intake often is depressed. The depressed appetite probably is related to rapid ruminal fermentation or lactic acid production when wheat is fed. There is some evidence that wheat type and variety affect ratios of metabolites produced during ruminal microbial digestion. Consumption of wheat has not been improved by an antihistamine, sodium bentonite, polyethylene cubes or higher roughage ratios. But, hydroxide alone and fat alone or the two added to wheat-based rations increased intake in recent Nebraska tests.

Rations containing high levels of wheat seem to be more satisfactory for summer than winter feeding. Normally wheat is priced most competitively with other feed grains during summer.

Table 6 includes results from adding 1 gram thiamine and 100 grams sodium bicarbonate to an all-wheat ration. The preliminary results are encouraging, but replication is necessary. The same study evaluated different proportions of wheat in fattening rations. Since the improvement in feed efficiency was proportional to the amount of wheat, the higher nutritional value of wheat is more complex than balancing a simple deficiency.

Although we have successfully fed 100 percent wheat in all-concentrate rations, it can be a treacherous grain because of its propensity to produce rumen acidosis. Where individual animal intake may fluctuate widely, as limited grain feeding on pasture, wheat should be used with great caution.

This paper is not intended to be a thorough compilation of beef cattle-wheat feeding research. Details of the studies mentioned have been published in recent Fort Hays Experiment Station Roundup Reports, Kansas Formula Feed Conference Proceedings, and Proceedings of the International Symposium on Wheat in Livestock and Poultry Feeds. Reports of trials using wheat in cattle rations also have been published recently by Kansas (Garden City Branch Experiment Station), Oklahoma, Texas Tech (Pantex), Arizona, California, Washington, Idaho, South Dakota, and Nebraska.

TABLE 6.--Different proportions of wheat in steer finishing rations. May 13, 1971, to September 11, 1971--122 days

Item	100 Percent milo control 19[2] Lot 2	75 Percent milo 25 percent wheat 19[2] Lot 2	50 Percent milo 50 percent wheat 20[2] Lot 2	100 Percent wheat 20[2] Lot 2	100 Percent wheat + thiamine + $NaHCO_3$ [1] 10[2] Lot 1
Average initial weight, lb.[3]	885	890	889	887	885
Average final weight, lb.	1,216	1,209	1,221	1,196	1,216
Average total gain, lb.	331	319	332	309	331
Average daily gain, lb.	2.71	2.62	2.72	2.53	2.72
Average daily intake, lb.:					
Forage sorghum silage[4]	11.3	10.3	10.2	9.5	9.5
Rolled milo	19.3	14.5	8.9	0.1	0.1
Rolled wheat		4.1	8.9	15.6	16.2
Carrier supplement[5]	1.0	1.0	1.0	1.0	1.0
41 percent protein supplement[6]	1.5	1.3	1.1	0.7	0.7
Air dry total	25.6	24.4	23.3	20.6	21.2
Average lb. feed/cwt. gain:					
Forage sorghum silage	417	393	376	377	351
Rolled milo	713	556	328	5	5
Rolled wheat		158	328	615	594
Carrier supplement	37	38	37	39	37
41 percent protein supplement	55	51	41	30	28
Air dry total	944	933	859	815	781
Estimated net energy values for wheat					
NE_m, Mcal./cwt. air dry		84	94	91	95
NE_p, Mcal./cwt. air dry		55	61	60	61
1 lb. milo replaced by 1 lb. wheat		1.04	1.24	1.20	1.26
Value of wheat relative to milo at $2.00/cwt., $/bu.		$1.40	$1.68	$1.62	$1.71
Feed cost per cwt. gain, $[6]	$21.23	$20.85	$18.92	$17.54	$16.80

[1] Received 1 g. thiamine mononitrate and 100 g. sodium bicarbonate in addition to basal wheat ration. Cost of thiamine and $NaHCO_3$ not included.

[2] Number of head.

[3] Initial weight with 4 percent pencil shrink; final weight equals hot carcass weight times 1.613.

[4] Silage intake limited to 7 lb. per day after reaching full feed.

[5] Carrier supplement includes 0.4 lb. dehydrated alfalfa, 0.1 lb. calcium carbonate, 0.1 lb. calcium chloride, and 0.025 trace mineral, stilbestrol, vitamin A, Aureomycin premix.

[6] Fifty percent of protein equivalent from urea and 50 percent from cottonseed meal.

[7] Feed costs based on: silage, $10/ton; milo, $44; wheat, $42; carrier supplement, $78; 41 percent protein supplement, $73.40.

POPPED GRAIN AS A VEHICLE FOR LIQUID SUPPLEMENTS

By H. G. Walker, Jr., G. O. Kohler, and Charles Metro, Jr., Western Regional Research Laboratory, Agricultural Research Service, United States Department of Agriculture

Today I would like to talk about some cooperative work, funded by Agway, Inc. of Syracuse, New York, that was carried out recently at our laboratory. Much of the work was done by Bud Metro.

We know that livestock production costs have shown a continued increase during the past years and that milk and meat prices have not increased proportionately. Consequently farm profit margins have been severely cut and new ways to lower the all-important feed costs must constantly be investigated and developed. Feed consumed by cattle is used largely for maintenance and production. Energy not supplied by forage is usually supplied by grain, but this may not always be the cheapest supply of dietary calories. At coastal deep-water ports, cane molasses is frequently a cheaper source of calories than corn or other grains but its use in feeds is somewhat limited. Since it is a liquid, molasses cannot be used at levels of much over 10 percent in conventional feed handling facilities. Consequently, there is a real need for a molasses carrier that would make it possible to make a free flowing solid feedstuff having 25 to 50 percent of molasses incorporated in it. Besides being a cheap source of energy, molasses is an excellent solvent for nonprotein nitrogen and is a useful platability enhancer. Oilseed meals have traditionally been used to provide the major protein content of ruminant rations, but because of the relatively high cost of these meals, molasses based nonprotein nitrogen liquid supplements have become increasingly important in today's carefully formulated least-cost livestock rations. Typically these liquid supplements include molasses, a nonprotein nitrogen source like urea or ammonium polyphosphate, and mineral salts.

Although some work has been done on carriers for molasses and liquid supplements, little quantitative data have been reported. For example, it is claimed that a soybean and sweet potato meal mix can carry 80 percent molasses when processed with saponins, tapioca, and dried (7). A feed product has been reportedly produced from 75 percent molasses and 25 percent cane pith by allowing fungi to break down the gums in the molasses (4). One report states that a high-percentage of molasses can be added to alfalfa when the legume is in the fresh-cut state (1). Corncobs have been shown to carry 40 to 65 percent molasses. Flax plant byproduct reportedly mixes well with 45 percent molasses[1] and used newspaper can be mixed and fed with 75 percent molasses (2).

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[1] Agway, Inc. Unpublished data.

The problem with exotic products like these is that in many cases they are fibrous, low quality products. They are expensive to ship before use and add little or nothing to the resulting value of the product. An improvement on these feeds would be a product with a high-percentage of molasses (at least 50 percent by weight), on a highly digestible, high energy carrier, which could be cheaply and easily produced and which could be mixed, pelleted or cubed, stored, handled, and fed without undue expense. It occurred to us that a grain derived product like popcorn might serve as an energy rich carrier for a liquid supplement. Most of us are familiar with the concept of such a material since we have all, at least as kids, enjoyed "Cracker-Jack."

Several years ago we designed and built a machine to "pop" grain, or explode it by dry air heat (3). A photograph of our machine is shown in figure 1. This machine was capable of handling about 1 ton/hour and was the prototype that served to inspire several commercial machines. The machine was especially effective in producing an expanded milo product. When the moisture content of milo was raised from the usual 11 to 12 percent to 18 to 20 percent, a product with up to 75 percent fully expanded material was obtained. Popping expands milo up to 9 to 12 times its initial volume, but wheat, barley, and corn expand to only 1-1/2 to 2 times their normal size. Now a new commercial machine, based on high pressure steam exploding of grain promises to expand wheat, corn, oats, and barley to the same extent as milo so that what we report today on milo ought now to be directly applicable to these grains as well[2].

A fairly large number of cattle feeding studies with popped or exploded grains have indicated these materials are superior feedstuffs in that they produce as good or better gains than steamed-flaked grains. Also, processing costs are lower. Feed intake is somewhat decreased with popped grains but this is offset by a corresponding increase in feed efficiency. Artificial rumen studies show a favorable increase in total volatile fatty acid production and in the propionate/acetate ratio. There seems to be no question that popped grains are effective feedstuffs (5)--the problem is how to utilize them effectively as carriers of liquid supplements.

The difficulty lies in the fact that exploded grains do not have a spongelike structure (6). Figure 2 shows a scanning electron micrograph of popped milo. It is apparent that each cell has expanded considerably. Unfortunately, each cell has also maintained the integrity of its own cell walls so that a closed pore structure is obtained rather than an open pore network. This means that in the closed cell, honeycomb-type structure, liquid that is introduced must pass through a lot of individual cell walls instead of flowing in freely through a series of interconnected canals. A vacuum expanded wheat product also has been found to have a similar closed cell structure.

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[2] Allen, Neal. Ross Machine Co. Oklahoma City, Okla. Personal communication.

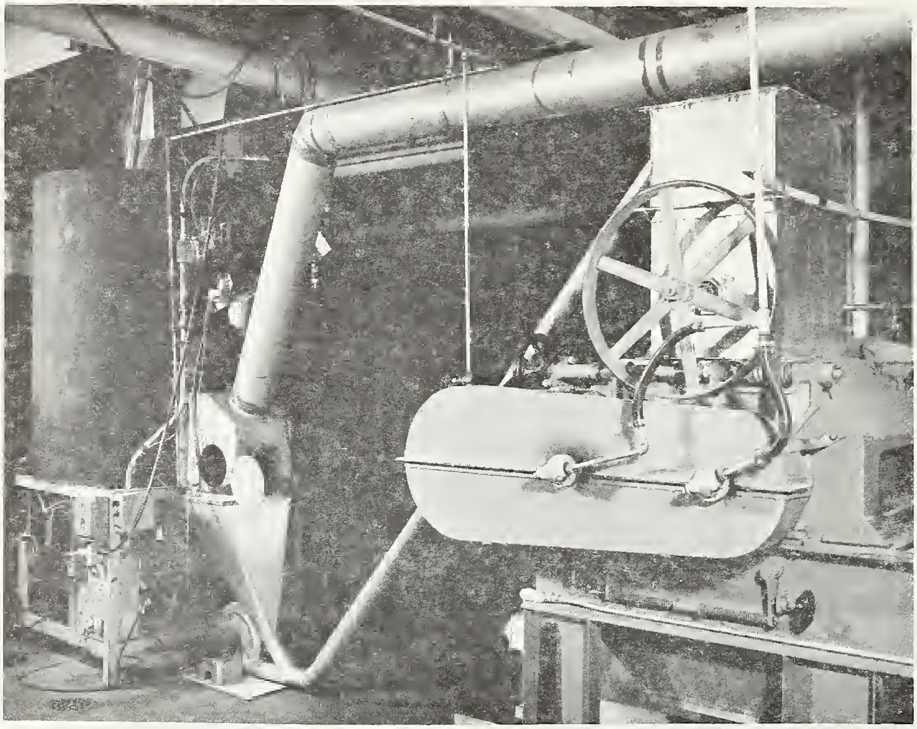

Figure 1.--WRRL grain popper and roller mill.

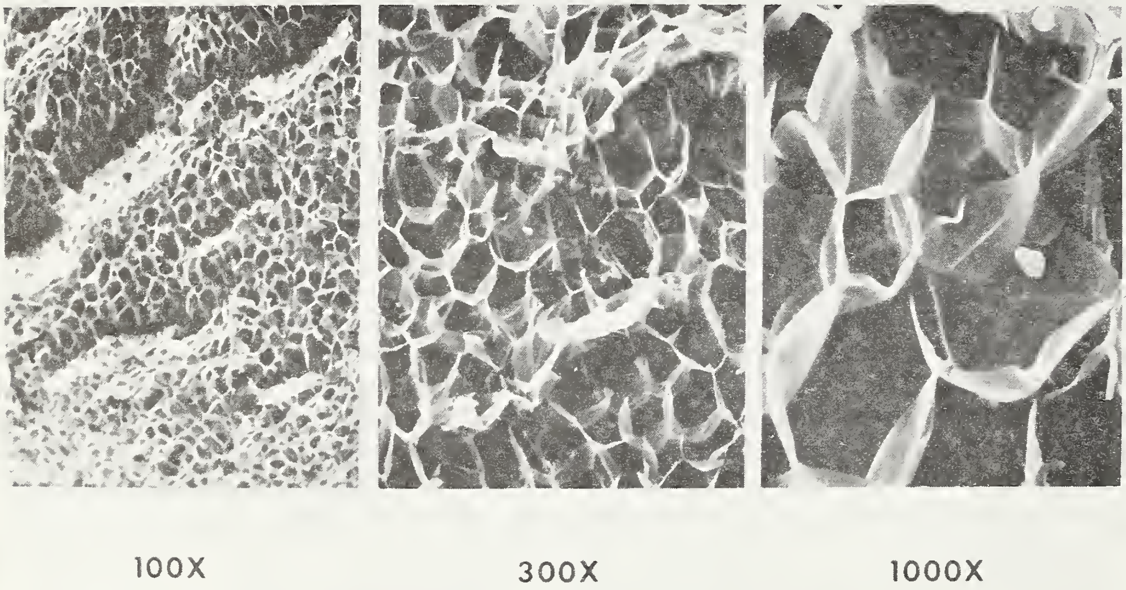

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Figure 2.--Cellular structure of popped milo-scanning electron photomicrograph.

Soaking popped milo in an aqueous dye solution for 20 minutes gave good penetration of liquid as shown in figure 3. After removal of the popped grain from the solution and draining for 20 minutes, it was found that the grain had absorbed two times its own weight of solution. Similar results were obtained with expanded wheat. Under the same conditions, unpopped grain absorbed only about 2 percent of its own weight of liquid.

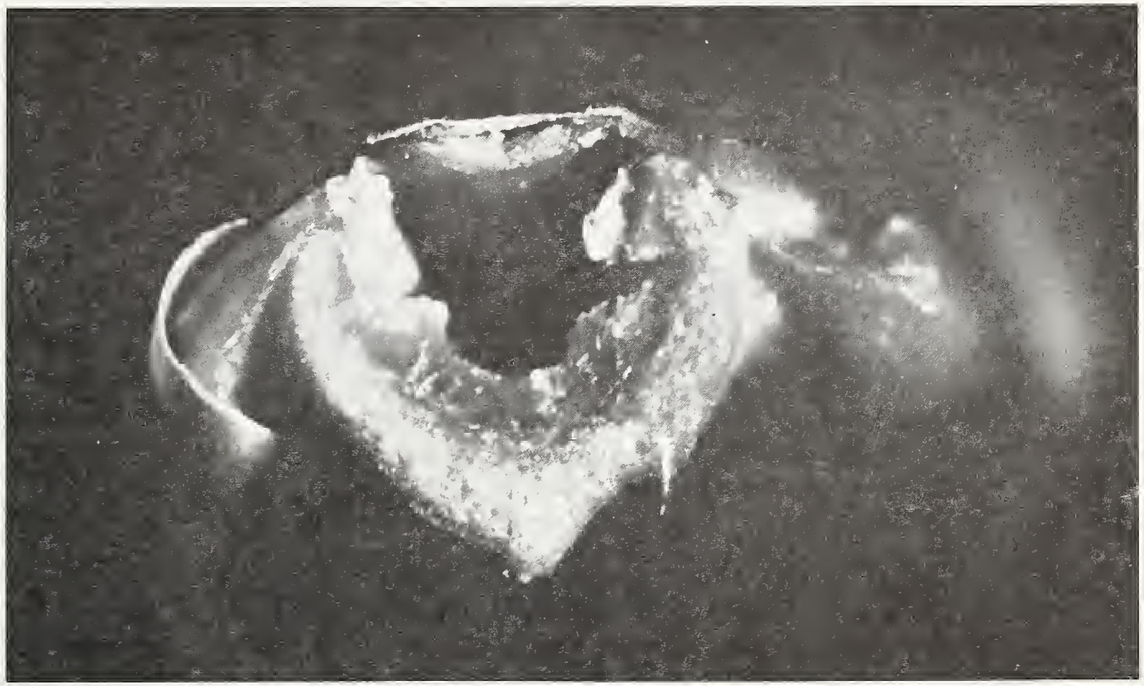

Figure 3.--Popped milo soaked in dye solution.

Results with the dye solution gave us hope that both popped milo and puffed wheat could possibly absorb molasses in a spongelike manner. However, when this was tried using 79.5° Brix molasses at 40° C. for 15 minutes, it was discovered that in contrast to the aqueous system, a viscous liquid, like molasses, could not pass through the interstitial barriers in exploded grains. Figure 4 shows a popped milo grain with only the outside holding any molasses.

Attempts to increase absorption by lowering viscosity gave little advantage. Propylene glycol, phosphoric acid, and detergent lowered the viscosity but not enough to enhance the absorption into the milo. For example, figure 5 shows a grain of milo soaked in molasses containing 14 percent propylene glycol, and it is evident that little has been accomplished.

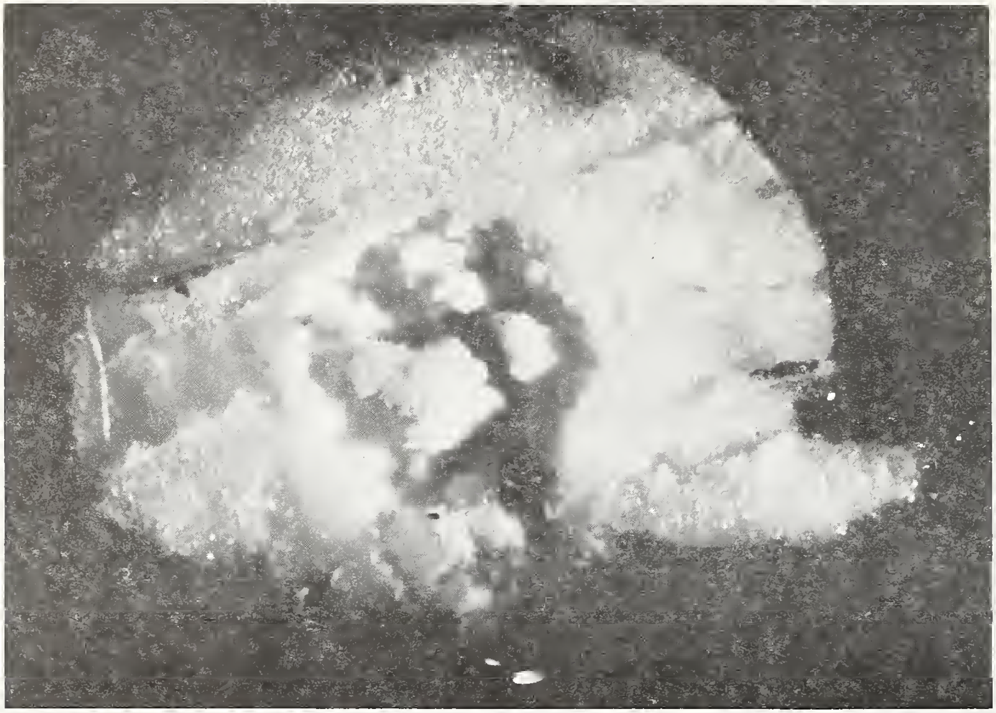

Figure 4.--Popped milo soaked in molasses.

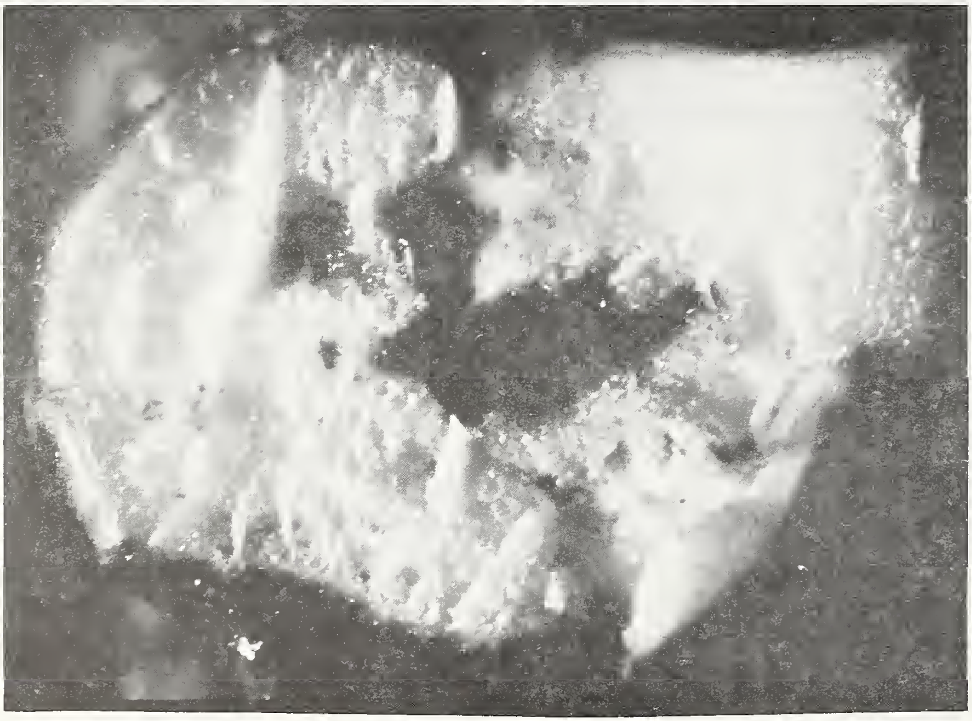

Figure 5.--Popped milo soaked in molasses with 14 percent added propyleneglycol.

Diluting the molasses with water produced a liquid which could penetrate the expanded grains fairly well after 15 minutes. Since this liquid contained one part of water to one part of molasses, it would be very unfavorable for use in commercial feed production because of the need for extensive redrying. Heating molasses to 40° C. gave better results because at that temperature the viscosity of molasses is lowered enough to allow it to slightly penetrate the outer layers. Higher temperature tended to burn the molasses but might be feasible with careful temperature control.

Using 79.5° Brix molasses at 40° C., we tried to produce a handleable feed by adding the molasses to the whole popped milo and the whole puffed wheat. Milo could carry up to 35 percent by weight molasses while the puffed wheat could carry 50 percent, but both of these products tended to stick together since only the outside of the grains was covered with molasses. To counteract this, the molasses covered grains were dusted with popped, finely ground milo or wheat. This gave a concentration of powder instead of molasses on the outside surface of the grain and helped to reduce the stickiness. Tests showed this advantage lessened when the grain was placed in a high humidity chamber. The moisture caused the molasses to soak into the powder, causing the grains to stick together.

Tests with vacuum or pressure offered very little encouragement. A combination of 10 minutes vacuum and 10 minutes pressure (40 pounds) applied to premixed popped milo and molasses showed some absorbtion into the outer edges of the grains (especially in the highly expanded areas). Use of higher pressures could be useful but we did not pursue this line any further.

A study of the economics of vacuum puffing showed that while puffed wheat performed better in molasses absorption, the present production methods were far too expensive for feed production. Because of this the subsequent work concentrated almost totally on popped milo. However, the high-pressure-steam-grain explosion process just developed for feedlot use will reopen the whole subject of use of exploded wheat or corn.

As the whole popped milo would hold only 35 percent molasses in the whole kernel form, another processing step was necessary to raise the molasses holding capacity to 50 percent or greater. Two alternatives to increase the holding capacity were apparent. The first was to increase the surface area and the second was to open up the intracellular voids, allowing the liquid to flow in. Various standard rolling and grinding techniques were used. Flat rolls crushed the product but did not rip it open to increase liquid absorption. Figure 6 shows that material produced in a differential roller mill was more desirable. It was both crushed and ripped apart. The action of the differential rolls increased surface area and exposed voids creating pockets to hold the molasses.

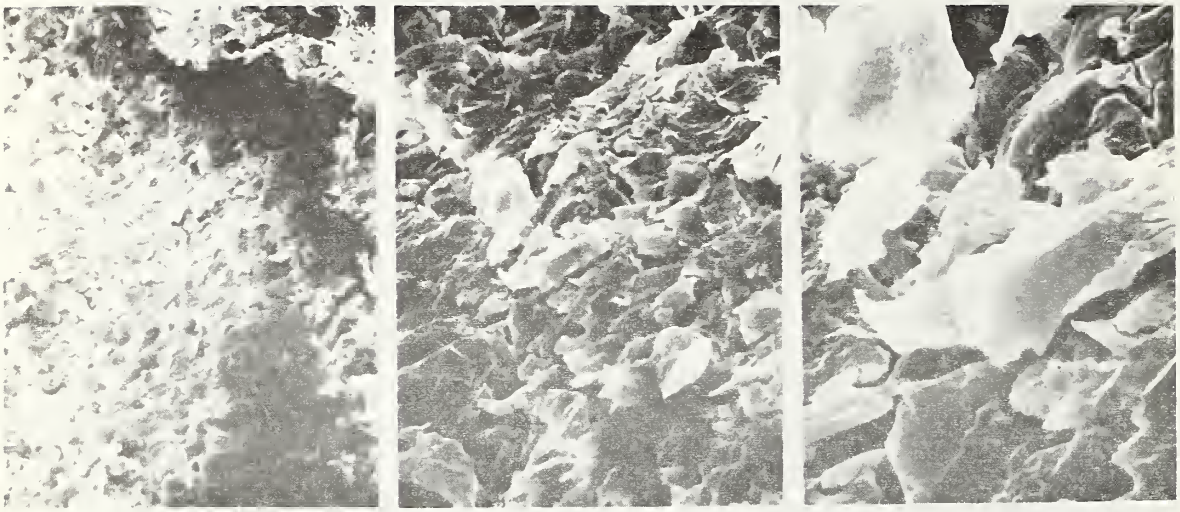

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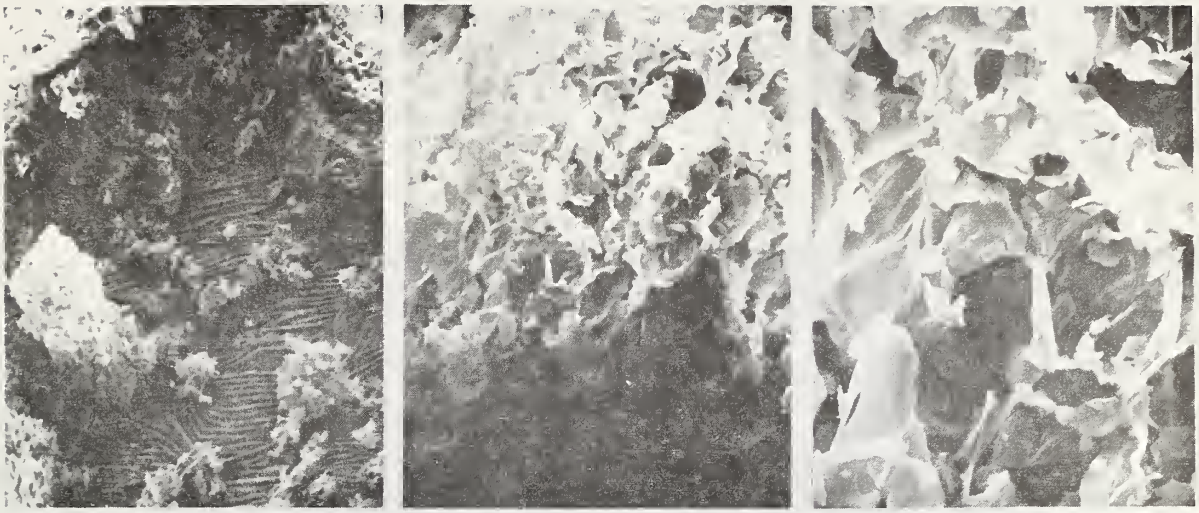
Figure 6.--Popped milo: Flaked in corrugated-differential rolls, 6/1,000 inch setting.

The holding capacity of this product increased to 48 percent, for a free flowing, nonadhesive product. Though rolling increased surface the results were not up to the desired level. Still greater surfaces had to be created with more voids exposed to soak up the molasses.

Grinding proved excellent for this purpose. A variety of grinding machines were investigated. Figure 7 shows how grinding increases the surface area by creating a number of small pieces that have many external pockets to hold additional liquid. The best product we made was ground in the Raymond Laboratory Hammer Mill using a 0.024 inch screen. This meal held 55 percent molasses in a free-flowing, nonadhesive form. The particle size distribution in this material was determined by using Tyler screens. Results (table 1) indicate that a fairly fine product is necessary for good carrying capacity. Ninety percent of the material screened passed through the 60 mesh screen.

The product from the Raymond mill, plus 55 percent molasses when pelleted in a laboratory California pellet mill, was acceptable but did not produce a high quality pellet. But when this product was used in complete rations at the level of 50 to 60 percent, a firm pellet was obtained which could be easily handled and fed to animals. The most acceptable pellets were made with a 3/8-inch diameter by 3/4-inch thick die as less friction was developed with this die than with the other available dies.



100X 300X 1000X

Figure 7.--Popped milo: Ground in hammer mill, 1/32 inch screen.

TABLE 1.--Particle size distribution of "best" product

Retained on screen size (mesh/inch)	Percent
35	1.0
48	1.5
60	3.25
100	30.6
150	17.1
200	18.9
Through all	27.7

Cubing was superior to pelleting. Our best product was a 2 by 2 by 1/2-inch cube containing all the nutrients needed by the ruminant except roughage. Cubes contained about 35 percent molasses in the complete ration. Pressing in the Norwalk press for 5 minutes at 23° C. and 850 pounds produced a cube equal in quality to 15 seconds at 23° and 15,000 pounds in the Carver press. If the warm material was pressed fresh from the mixer a firm, desirable cube resulted. If the material was cold, the cube did not compress as well but heating to 40° solved this problem. Figure 8 shows the 55 percent molasses-grain mix, and cubes and pellets made from it. Cubes could be made just as well from liquid supplements as from straight molasses. The major drawback to cubing was that a machine capable of producing cubes at commercially acceptable rate was not available to us at the time to evaluate the process in a large scale operation. A commercial briquette machine should be suitable for production of a high quality product.

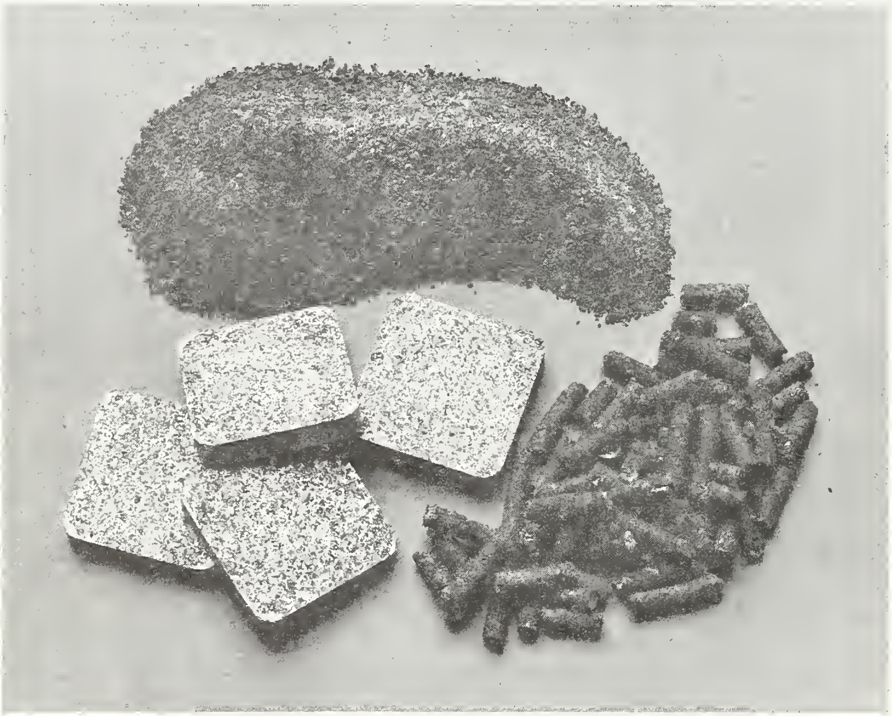


Figure 8.--Pellets and cubes made from 55 percent molasses--45 percent ground popped milo.

Tests on the products for moisture damage and compactability on storage showed they were effected by both. All molasses products became sticky when placed in the 70 percent relative humidity environment and eventually showed some mold growth. The meals became moldy within 2 weeks, the pellets within 3 weeks, and the cubes within 4 weeks. We concluded that high molasses products cannot be subjected to damp storage conditions for extended periods without external packaging protection.

Of all the meals tested under pressures simulating stacked storage conditions, popped milo ground in the Raymond Hammer Mill with the 0.024-inch screen mixed with 50 percent molasses was the best. It could be easily broken up after 84 hours under moderate pressure.

A drawback of the 55 percent liquid containing product lies in the need to screen off 25 percent of the unpopped material after popping, allowing only 75 percent of the original grain to be used. This step can be eliminated if the liquid supplement or molasses level is dropped to about 40 percent. An alternate solution may lie in the use of steam popping to replace hot-air popping, because this method reportedly gives a 100 percent pop with milo, corn, barley, or wheat.

Summary

To summarize briefly, ground popped grains are excellent carriers for molasses or nonprotein nitrogen liquid supplement. Because of their closed pore structure, popped grains must be rolled or milled if they are to carry the maximum weight of viscous liquid. Free flowing, ground popped grain products containing 55 percent of molasses or supplement can easily be incorporated into pelleted or cubed nutritionally complete rations.

Acknowledgment

We wish to thank Agway, Inc., Syracuse, N.Y., for financial support for this work. We are indebted to Francis T. Jones of the Chemical Physics Laboratory of this Division for the regular and scanning electron photomicrographs used as figures.

Literature Cited

(1) Arnold, C. D. Feed mixtures containing molasses. U.S. Patent No. 1,996,395. 1935.

(2) Kessler, E. M., Chandler, P. T., and Branding, A. E. Dry molasses product using waste paper for possible cattle feed. J. Dairy Sci. 50:1994. 1967.

(3) Rockwell, W. C., Lowe, E., Walker, H. G., Jr., and Morgan, A. I., Jr. Hot air grain popping. Feedlot. 10(11):42. 1968.

(4) Roth, G. Biological treatment of molasses meal to reduce stickiness. Proc. 42d Annual Congress S. Afr. Sugar Tech. Assoc., p. 57. 1968.

(5) Walker, H. G., Jr., Lai, Bet, Rockwell, W. C., and Kohler, G. O. Preparation and evaluation of popped grains for feed use. Cereal Chem. 47:513. 1970.

(6) Walker, H. G., Jr., and Reeve, R. M. The microscopic structure of popped cereals. Cereal Chem. 46:227. 1969.

(7) Winn, R. M. Blackstrap molasses production. U.S. Patent No. 3,033,684. May 8, 1962.

TRENDS IN WHEAT GENETICS AND BREEDING

By K. A. Lucken, North Dakota State University

Plant breeding begins with the creation of genetic variability. Our ability to improve the chemical and physical properties of the wheat kernel and the yielding capacity of the wheat plant depends on our knowledge and skill in manipulating the genes that control these characteristics. Today, I will discuss some "new dimensions in genetic variability." These are developments in wheat genetics and breeding which expand our potential ability to create or use genetic variability.

Homeologous Chromosome Pairing (5B Method)

Our bread wheats belong to the taxonomic subtribe TRITICINAE and can be crossed directly--or indirectly through various bridging techniques--with most members of this subtribe. But breeders still have limited access to this germ plasm pool and can, only with great difficulty, incorporate economically useful genes from certain species into bread wheats. Much of this difficulty in transferring genes can be accounted for by a genetic system into which wheat geneticists have gained considerable insight over the past decade.

Ancestrally, the three genomes, A, B, and D,of bread wheat are related to one another and to the genomes of other species in the TRITICINAE (e.g., Aegilops, Secale, Agropyron). However, in most crossing situations, related chromosomes of different genomes (homeologous chromosomes) do not pair with one another during meiosis, and thus gene exchange between these chromosomes does not occur. The discovery that pairing between homeologous chromosomes is genetically controlled by chromosome 5B provides the basis for manipulation of the system to allow homeologous pairing. Several procedures can be used to achieve the desired cytogenetic condition. Basically, they produce a plant, lacking chromosome 5B, in which pairing and crossing over occur between homeologous chromosomes--either between wheat chromosomes and chromosomes from alien species or among the genomes of bread wheat itself. These procedures allow two types of genetic change. The dosage of a favorable gene within bread wheat can be increased by transfer from one genome to one or both of the other genomes. And desirable genes from other species in the TRITICINAE can be transferred to wheat.

History indicates the potential practical implications of gene introgression in wheat. Genes for stem rust resistance derived from the tetraploid emmer wheats (in Thatcher and Hope wheats and their derivatives; and in Stewart, Wells, and Leeds durums) have provided many years of protection to U.S. wheat growers. The 5B technique has been used successfully by Ralph Riley to transfer genes for rust resistance from Aegilops comosa to bread wheat. It will undoubtedly find extensive use in transferring genes for disease resistance. Less predictable, but equally exciting, is the potential for reconstituting the wheat genome in terms of genes affecting quality and yield.

Wheat breeders have not yet used the 5B method in breeding programs. However, the progress being made by Drs. Ralph Riley, E. R. Sears, C. J. Driscoll, and other geneticists in developing techniques and genetic stocks should ultimately provide breeders with efficient and effective means of gene introgression and manipulation.

Cytoplasmic Variability

Traditionally, plant breeders have attached little significance to the cytoplasm as a source of genetic variability. During the past 2 years, however, the threat of southern corn leaf blight to corn hybrids with T cytoplasm has focused attention on the limited knowledge of cytoplasmic genetics in higher plants and pointed out the importance and need for further study of the cytoplasm. Also, in the past decade, geneticists and biochemists have elucidated a genetic system in mitochondria and chloroplasts, involving DNA and similar to that of procaryotes, providing further proof that the cytoplasm is an important vehicle of genetic variability.

A byproduct from hybrid wheat research has been the discovery of several different cytoplasms among wheat and its relatives and the development of procedures to study cytoplasmic variability. The results, many of them unexpected, suggest that these genetic stocks and methods may have application in wheat genetics and breeding far beyond the original intent of a mechanism for pollination control in the production of hybrids.

Eleven distinct cytoplasms now are known in Triticum, Aegilops, and Secale. Several more will likely be identified in the near future. Identifying a cytoplasm is accomplished by introducing the genome of one species, usually bread wheat, into the cytoplasm of a second species through backcrossing. Cytoplasms are distinguished by the morphological effects they produce in bread wheat, i.e., male sterility, pistilloidy, late maturity, low plant vigor, or by their interaction with specific nuclear genes for pollen fertility restoration.

Although the alien cytoplasms adversely affect fertility, growth rate or plant vigor, they also are the key to identifying nuclear genes which interact with cytoplasmic factors. Thus, nuclear genes which overcome or nullify the deleterious effects of the alien cytoplasm can be recognized in early backcrosses and transferred from the species donating the cytoplasm to the bread wheat genome. For example, wheat plants with einkorn cytoplasm are abnormally weak unless they have nuclear genes--derived from einkorn--that restore normal plant vigor. Our knowledge of these types of genes is, at present, limited. They are not normally found in the cultivated, hexaploid wheats. But diploid and tetraploid species--with their specific cytoplasms--apparently have an obligate requirement for particular nuclear genes to produce normal, fertile plants. Although normal bread wheat does not require these genes, the question, "What is their effect on yield or quality?" is sufficiently interesting to merit further study.

In our program, we currently are studying the relationship between genes that restore pollen fertility and grain protein content. Restorer lines and hybrids with high protein have been found in several hybrid wheat programs. These observations plus the chromosomal location of the restorer genes indicate that the effect these genes have on protein synthesis should be clarified to determine if they have possible use for increasing protein content in conventional wheat cultivars.

Hybrid Wheat

Up until the present, hybrid programs still have not really been hybrid breeding programs in the sense that they are routinely evaluating hybrids or the yield increases possible from hybrids. Instead, they have been concerned with developing a stable, reliable system for producing hybrids and, for the last few years, with improving parental stocks.

The difficulties encountered in developing male parents (the fertility restoration problem) also have so far negated one major advantage foreseen for hybrids. Breeding hybrids should be a substantially more efficient procedure for obtaining a desirable end product than breeding standard varieties. Many otherwise outstanding lines are discarded in breeding programs because they possess a few major or minor faults--frequently of quality. In a hybrid program, parental combinations can be planned so as to complement and overcome the deficits of one or both parents and result in more rapid achievement of the desired performance level.

Several developments during the past year indicate that simple procedures for developing hybrid parents are possible and that the efficiency inherent in a hybrid program will be realized.

First, intense selection and introduction of more genes have successfully increased fertility restoration levels in restorer lines within the widely used *T. timopheevi* system. In wheat growing areas where fertility restoration is less of a problem, these lines should be adequate for hybrid breeding.

Second, in our own program we have developed several new fertility-sterility systems. Used as alternatives or supplements to the *timopheevi* system, these show promise for greatly simplifying restorer line breeding and stabilizing seed set on F_1 hybrids. We think breeding for fertility restoration soon will become relatively straightforward rather than the discouraging, seeming almost insolvable, problem it has been in the past.

Recently, P. L. Rowell and D. G. Miller have reported that the chemical Ethrel acts as a male gametocide and induces high levels of male sterility in wheat. Essentially, a gametocide allows one to take two conventional wheat varieties, plant them in alternate drill strips, and spray the line selected as female with the chemical. This line will then cross-pollinate with the male line and hybrid seed will be obtained.

Ethrel is a far more effective male gametocide than we had thought possible based on previous experience with other chemicals. However, it is still a bit early to make definite judgments on large-scale use of Ethrel. Dosages, application times, varietal differences, and environmental interactions need further study.

These data from hybrids grown at Fargo (table 1) are representative of our current hybrid yield results.

TABLE 1.--Comparative yields of hybrids and conventional cultivars, Fargo, N. Dak.

Type	Bushels/acre 1970	Bushels/acre 1971
Waldron	43	56
High hybrid	46	66
High exp. line	49	66
High 5 hybrids	44	61

Improving restorer lines agronomically and for fertility restoration potential has resulted in concurrently higher yields in their hybrids. Presently the better hybrids yield equal to or greater than standard varieties and at a level near the best experimental lines. However, both these male parents and their hybrids still have many obvious defects. Our quality data are very limited but no major problems have yet been revealed.

The yield data so far lead me to believe that yield increases of 10 percent or so better than the best varieties will be relatively easy to achieve. With further improvement of parental stocks, hybrid combinations that conceivably should yield much better than present hybrids can be tested. But whether hybrids yielding 20 to 30 percent higher than the best standard varieties can be produced is still an unknown quantity. Many data addressed to this question are forthcoming over the next few years.

Hybrid seed production is a large topic and I will not go into it today except to point out the scope of hybrid seed production (table 2).

There were approximately 48 million acres of wheat grown in the United States during the past year! Producing hybrid seed to plant part or all of this acreage is at the same time the "captivating force" and the "monumental task" for commercial companies.

TABLE 2.--Estimated acreage required to produce 1 million bushels of seed wheat

Seed production method[1]	Acres	Bushels seed wheat
		Million
Current (varieties)	33,333	1
Hybrid seed		
Drill strip (1:1)[2]	88,888	1
Drill strip (2:1)	66,666	1
Blend (5:1)	53,332	1
Blend (9:1)	49,382	1

[1] Assumed: 30 bushels/acre yields; 75 percent seed set.

[2] Female: male ratio.

Semidwarfs

Less than 10 percent of our Great Plains wheat acreage currently is planted to semidwarfs. Undoubtedly, this acreage will increase in the next few years although the full extent of the increase is not at all clear or predictable at present.

First, these remarks are confined to the spring wheat area with which I am familiar since semidwarf evaluation is closely connected with production practices. Benefits or problems other than the ones discussed here may be important in other areas.

The genes for semidwarfism illustrate the profound effect even the introduction of a very few genes can have on a wheat breeding program and on wheat production practices. However, introduction of new genes into a breeding program also creates new problems and the need for reevaluation of old objectives and procedures. Breeding problems associated with semidwarf germplasm in spring wheat programs include sterility, low test weight, leaf firing, and susceptibility to foliar diseases, and low grain protein and baking absorption. Sterility and low test weight are easily overcome and reoccur infrequently in the breeding material. Leaf firing and foliar diseases have been more persistent problems particular with some sources of semidwarfism and in the durum wheats. We are having some difficulty evaluating the actual need for good, green leaves on a plant especially at later growth stages. Nevertheless, several semidwarfs with excellent leaf characteristics have and are being developed.

The most serious problem with semidwarfs in North Dakota is that they frequently have 1 to 2 percent lower grain protein and 1-1/2 to 4 percent lower baking absorption compared with the conventional height varieties used as standards. Even with severe selection these deficiencies have proved difficult to overcome, and only in the past year have semidwarfs with potential acceptibility for these traits been identified among North Dakota breeding lines. An obscure picture of cause and effect relationships still exists as to whether high yield alone, the genes for semidwarfism themselves, the linkage group involving these genes, or combinations of these factors cause the reduced protein and baking absorption.

A list of the most important factors influencing the distribution of semidwarfs in North Dakota must include:

1. Success in developing high yielding, stiff-strawed conventional height varieties.

2. Success in developing semidwarf types that compete effectively with wild oats and foxtail--or effective weed control by herbicides.

3. Success in increasing protein content and baking absorption of semidwarf types.

Most comparisons of semidwarfs with released standard height varieties over the past few years show substantial yield advantages for certain semidwarfs. However, the lodging resistance of semidwarfs can also be achieved by developing somewhat shorter, stiffer-strawed conventional types exemplified by the variety Waldron.

Several stiff-strawed experimental lines yielding comparatively with the best semidwarfs have been developed by R. C. Frohberg and R. H. Busch in the North Dakota breeding program (an example in table 3). These lines indicate that semidwarfs do not necessarily have an inherent capacity for yield that cannot be attained through conventional height varieties.

TABLE 3.--Comparative yields, North Dakota, 1970

	Bushels per acre grown at--			
Type	Fargo	Minot	Carrington	Langdon
Waldron	43	35	58	50
High semidwarf	46	38	65	62
High conv. variety	48	36	71	57

In North Dakota, a crop must compete effectively with wild oats and other weeds; some semidwarfs appear deficient in this respect. Under certain conditions semidwarf types have been excessively short. The point is that these considerations do not yet lead to a clear-cut basis for determining what relative emphasis should be placed on semidwarf types and on stiff-strawed conventional types in our breeding program.

Summary

Wheat improvement is a slow steadfast process. Attention to many details of disease resistance, quality, and agronomic characteristics plus extensive testing all are requirements for producing a superior cultivar. And there has been progress in all these areas.

One concern is whether our ability to improve wheat yields is increasing at a faster rate than our ability to maintain or improve protein content. Perhaps some of the "new dimensions in genetic variability" described in this paper may help alleviate--in some yet unpredictable manner--the continuing problems of protein content and quality.

PROBLEMS IN WHEAT CLASSING

By Robert L. Albert, Consumer and Marketing Service, United States Department of Agriculture

Are there any significant problems connected with the classing of wheat? The answer is emphatically "yes"--more so with every passing day.

About 93 percent of all wheat grown in the United States is common wheat (Triticum aestivum). This species is extremely important to us because the flour made from it it superior to that from other species insofar as leavened breadmaking is concerned. Flour made from some varieties of common wheat is also suitable for production of pastries, cookies, crackers, biscuits, and the like. Common wheat may have red or white kernels and may have either spring or winter growing habits.

What is quality? Quality of wheat is a relative concept. To the grower, wheat quality may include:

--- yield, in terms of bushels per acre
--- resistance to disease and pests
--- adaptability to soil and climate
--- resistance to lodging
--- protein content
--- the grade
--- dockage.

To the country elevator operator, it may include:

--- protein quality and quantity
--- the grade
--- dockage.

To the miller, wheat quality includes:

--- protein quality and quantity
--- specific gravity
--- clean-out (dockage, foreign material, shrunken and broken kernels)
--- kernel size and shape
--- hardness
--- flour yields and ash content.

The baker considers wheat flour quality in a great number of ways. Some are:

--- volume of the bread loaf
--- dough mixing time
--- product color and texture
--- cookie diameter and thickness

Each segment in the industry--from the grower to the baker--has its own set of values concerning wheat. They each have their own diverse methods of determining the wheats (or flour made therefrom) which they wish to handle. Further, members of each segment may individually differ in their desires and methods for testing prospective lots of wheat before purchase.

One thought which all or most seem to have in common is that they usually consider the class of wheat as a basic criteria in determining the value of a purchase or a sale. Inspection certificates issued by official grain inspectors, based on Official Grain Standards of the United States, have been of great value in these transactions because they state the class of the particular wheat inspected--in addition to other valuable information.

The many varieties of common wheat differ, in varying degrees, in their ability to satisfy the individual needs of growers and producers. Characteristics of any single variety may vary widely when grown in different locations--sometimes only a few miles apart from one another.

Traditionally, common wheats have been classed according to their kernel color, kernel hardness, and growing habits. Each group, happily, displayed kernel characteristics which were somewhat distinctive and, therefore, discernible by an inspector or other knowledgeable individual. The Official Grain Standards of the United States utilizes these groupings in classifying common red wheats. They are:

--- Hard Red Spring (HRS)
--- Hard Red Winter (HRW)
--- Soft Red Winter (SRW)

Flour from the hard red wheats is normally regarded as best for breadmaking because of its desirable gluten quality and quantity. Hard wheats mill into flour with a granular character which is considered to be a desirable quality for bread flour. Some industry segments regard HRS wheat as superior to HRW wheat for breadmaking; others do not. SRW wheat is used primarily for cracker, pastry, cake, and cookie flours--or mixed in varying degrees with the hard red wheats for breadmaking flour.

Class is determined by inspectors on the basis of the visual characteristics of the kernels in the sample taken from the lot of wheat offered for inspection. The inspector, drawing on his background of training and experience in identifying wheat kernels as to class--and even to variety (there are about 200 recognized varieties of commercially important wheat in the United States)--makes his determination by visual, subjective means.

Wheat classing is becoming increasingly more difficult, however. In fact, the entire concept of wheat classing by visual means is becoming, or already is, obsolete. The cause--an upsurge of new varieties whose kernel characteristics, growth habits, and end-use potentials have literally upset many of the "old standards." In the past, one could usually follow the rule that wheat planted in the spring would look, mill, and bake like spring wheat and would be classed as such; the same held true for winter wheat.

These guidelines are not dependable in identifying the new varieties. Outstanding examples of these new, hard-to-identify varieties are the dwarf and semidwarf wheats. They can resemble one of the classes HRS, HRW, or SRW wheats or appear as a mixture of them, depending upon soil and climatic growing conditions. This is less difficult to understand if one studies the parentage of the semidwarfs. Briefly stated, many of them are crosses and recrosses of HRS, SRW, HRW, and white wheat varieties. Further, the quality of a variety may vary from very poor to excellent when planted in different locations, even within the same State. Visual kernel characteristics may also vary widely, within a variety, according to growth, location, and environment.

In Canada the release of varieties is controlled by the Government. Only varieties with distinct kernel characteristics and known qualities are being released. In the United States, when kernel characteristics are not distinct, inspectors have been instructed to class the wheat as HRW. In addition, we have proposed using the sedimentation test as an aid in classing wheat which does not have distinct kernel characteristics.

Since wheat classing by visual kernel characteristics can no longer provide Government and industry with reliable basic wheat quality information, what will take its place? This question has been pondered for several years and as yet remains unanswered. Wheat quality separations and consolidations are first made by the hundreds of country elevators who are the first link in the merchandising chain. They need a test(s) for gluten quality and quantity which is:

1. rapid
2. simple
3. inexpensive
4. dependable
5. acceptable to the industry.

Research continues to seek an answer that will satisfy these five criteria. For example, various rapid methods for determining gluten content have been developed but so far have failed at least one of the above criteria. Of all the tests which have been applied to wheat for purposes of measuring overall gluten quality and quantity, the sedimentation test has come nearest to satisfying the five criteria.

The sedimentation test, developed by the U.S. Department of Agriculture, provides a measure of gluten strength and quantity. It is rapid, simple, and inexpensive. However, its dependability is open to question by members of the trade. When used as a basis for determining Government loan values a number of years ago, many traders felt the test was not dependable. As a result they are opposed to further use of it. This could be a serious mistake in the long run. A concentrated, unemotional effort should be made to improve the sedimentation test. Its reliability should then be subjected to a comprehensive study conducted on a statistically designed nationwide basis.

We must have an answer to the question: "What are we really describing when we speak of HRS, HRW, and SRW?" With this answer and the methodology to implement it, we can write standards that are truly effective and useful for all segments of the industry! To do this, old traditions, now outmoded, will have to be discarded--a painful process for some.

Summary

A. Under the United States Grain Standards Act there are six commonly recognized classes of wheat:

    1. HRS
    2. HRW
    3. SRW
    4. White
    5. Durum
    6. Red durum

B. The criteria for the classes include:

    1. Agronomic characteristics; i.e., winter or spring growing habit.
    2. Color; i.e., red or white bran
    3. Milling and baking properties; i.e., bread flour, cake flour, pasta, etc.

C. In grading wheat, class determinations are based on kernel characteristics; i.e., color of bran, shape of kernel, texture, etc.

D. A serious problem has developed in determining the class in common red wheat.

    1. Cause--New hybrid red wheats have been developed. The visual kernel characteristics of the hybrids may resemble HRS, HRW, SRW, or display a combination of characteristics. The milling and baking characteristics may resemble HRS, HRW, SRW, or a combination and may vary by origin.

    2. Current efforts to resolve the problem:

    Canada--In Canada where the release of varieties is controlled by the Government, only varieties with distinct kernel characteristics and known qualities are being released.

United States--When the kernel characteristics are not clear, inspectors have been instructed to class the wheat HRW. In addition, we have proposed using the sedimentation test as an aid in classing wheat which does not have distinct kernel characteristics.

3. The real problem--Kernel characteristics, even when distinct, are not a reliable means of determining milling and baking properties. A quick, simple, inexpensive, reliable, and acceptable test is needed to determine the principal milling and baking property; i.e., gluten quality and quantity, so millers can buy by class and obtain the desired milling and baking properties. The test must be usable at the country elevator level.

DEVELOPMENT OF FEED WHEATS

By B. J. Roberts, Cargill, Inc.

At the present time, we are faced with an unpleasant situation in the wheat industry. Our production is high; our export markets could be better, and farm prices are low. The subject of feed wheats is not a popular subject In fact, the term "feed wheat" is a dirty name within many parts of the wheat industry.

The farmer is not overly enthusiastic about feed wheats. A feed wheat to him means a reduced farm price, and at his present yield levels this would mean a reduced income per acre. The capital cost of farming has increased as well as interest rates and taxes. The farmer definitely is not interested in reducing his income per acre. The grain merchandiser objects even more to feed wheats because the advent of feed wheats means additional capitol investment for handling, storing, and merchandising another product. The miller objects to feed wheats since without separate handling procedures for feed and quality wheats, feed wheat could very easily contaminate quality wheat and result in a loss of efficiency in his mill, cause the miller to produce inferior products for his domestic and export markets, or both. The baking industry shudders at the thought of feed wheats because they fear that feed wheats will take over the acreage, and increase the cost of quality flours. The baking industry must have a reasonably priced and predictable raw material--flours--whereby they can program their production, and control the quality as well as the cost of their end product-bread. At this point, each of you, the grower, merchandiser, miller, baker, and even planner of government programs would be correct in asking,"Why even consider a feed wheat?" We breeders, and especially commercial breeders, have been asked this same question.

Wheat breeders have to look at the possible needs of the wheat industry not from the standpoint of last year, or next year, but what will the demands be in 15 or more years. What kind of wheat will be needed to supply these demands? It takes time to create a new type of wheat. A minimum of 8 or more years are required from the time a cross is made to the release for sale of a new variety. Thus the breeder is faced now with the question of what kind of wheat will be needed in 1980 and 1990, and what will be their end-product use. A general conclusion is that we will need high yielding, disease resistant, premium quality wheats to meet the demands for the domestic and export markets--wheats that will be all purpose wheats for food, feed, and industry. Greater economy in the cost of production, price of the wheat, and price of the end products will have to occur in order to compete for the dollar market, domestic as well as export. We now have four markets for our wheat: (1) Domestic food, (2) industry, (3) export, and (4) feed.

Domestic and Industrial Markets

Our annual domestic use of wheat for food, and use in industry, is at a fixed level of 600 million bushels. We cannot look for a drastic increase in domestic consumption unless we have a sudden explosion in our population, or a breakthrough in industrial need.

The wheat industry has asked for help from Federal, State, and private organizations to find new industrial uses for wheat. The Sixth National Conference on Wheat Utilization Research and this conference reported some of the progress in this direction. These investigations included the use of wheat in industrial alcohol, pulp and paper, rubber, plastics, flocculants, nonfood uses of gluten, adhesives, and as feed. The data reported in many of these studies indicated that wheat could be used, but its use was limited because of economics--the cost of wheat and the resulting cost of the end product.

_If_ a breakthrough in the industrial use of cereal grains should occur, can wheat compete with corn or sorghum in price? It has not done so in the past. Dimler (_3_) reported that corn and grain sorghum generally have been lower priced than wheat and, therefore, become the favored raw materials for industrial use. Products from corn and sorghum accounted for about 90 percent of the cereal products used industrially in 1963, while wheat accounted for just under 10 percent. Dimler also indicated that once an industry is established on the basis of a given grain, it is unlikely to change unless a significant price differential not only exists, but can be expected to continue for a number of years. Have we provided the proper economic environment for the expansion of wheat into industry, including the feed industry?

As a breeder anticipating the future use of wheat in 1990, I do not believe that wheat can be ignored as a possible raw material for industry. However, in order to do so, yields must be increased in areas where production per acre is normally high thereby stabilizing price and availability.

Export Markets

In the past we have enjoyed export markets with hard work by many organizations, private companies, and wheat commissions; a rather large export market for both dollar and government export.

The "Green Revolution" in India and Pakistan has had an effect on our recent exports and I expect this revolution to occur in other wheat importing countries, including Russia and China. The Green Revolution has increased the production of wheat in India from 12.3 million metric tons to an estimated 20 million metric tons in 1970. Production in Pakistan has jumped from 4.6 million metric tons to 8.4 million tons. During the past three wheat harvests, 1968-70, the Green Revolution has added to the gross agricultural product the equivalent in U.S. dollars of $1,850,000,000 in India and $850,000,000 in Pakistan (_1_).

The success of the wheat programs in India and Pakistan has been, in part, the success of young scientists trained in wheat research and production in the program of the International Maize and Wheat Improvement

Center (CIMMYT) of Mexico. There are researchers and economists who say, privately, that the Green Revolution will lose momentum, that it is a temporary situation. I don't believe this and I do not believe we should sit complacently hoping this will be the case. The governments of India and Pakistan have seen what research in agriculture can accomplish when objectives are defined. Governments of other wheat importing countries have seen what has happened and are now asking for and receiving help from CIMMYT. Just as important, the young scientists of these countries feel confident that they cannot only keep the Green Revolution moving but spread it to other countries. During the past 8 years, 140 young scientists have been trained by CIMMYT in wheat research. Training in early generation quality testing, as well as training in more sophisticated quality control, has been added to the program. I expect some of these countries to have a significant effect on our export markets by 1980. I believe the major part of our exports in 1980 will be governed by economics, price first--quality second. To compete successfully on an open market, we must have high yielding wheats with acceptable quality which are competitively priced to maintain the dollar export markets for food, industry, and feed.

Market for Feed Wheats

Our fourth market for wheat is the feed industry. Reitz (4) has reviewed the amount of wheat grain and millfeed produced and fed in the United States. The amount of wheat grain fed to livestock is a relatively small part of the total crop. Since 1964, the average has been about 110 million bushels per year or 3.3 million tons. In the case of corn about one-half of the crop is fed on the farm where grown as compared with one-thirtieth of the wheat crop. The byproducts of milling, primarily bran and shorts, were estimated at about 4.5 million tons annually and equaled 25 percent more in total weight than grain fed. The estimated total annual contribution of wheat to the feed supply is 8 million tons. Approximately 174.2 million tons of feed grains were produced in 1969. The use of wheat in the feed trade has been like the use of wheat in industry. The price has favored corn, sorghum, barley, and oats for feed.

Of the four markets, it appears that the most promising markets for increasing the use of wheat will be for feed and use in industry. The feed market is available now. The industrial market will have to be encouraged through research in utilization and marketing to provide an economic environment to stimulate industry to use wheat. However, to capture any significant part of these two markets, the price of wheat must be competitive with corn and grain sorghum.

Production of Feed Wheats

An international symposium entitled "Wheat in Livestock and Poultry Feeds" was held at Oklahoma State University in 1970. This symposium explored the nutritional and biological aspects of using wheat in rations of livestock, poultry, and game birds. The general conclusions of the investigation reported that wheat can be used successfully as feed. Wheat in today's rations is used primarily as a source of energy, carbohydrates. Wheat is equal in feeding value to corn in ration for dairy and beef cattle if no more than 50 percent of the grain ration is wheat. It should be rolled, cracked, steam-flaked, or pelleted for cattle. Digestive problems can occur but can be corrected by adjusting the formulation of the ration.

The proceedings of the symposium was reviewed as to the types and kinds of wheats that will be needed by the feed industry in 1980 and 1990. Some general conclusion can be made. Wheats with increased yield will be needed in order to maintain net income per acre for producers of feed wheats. Wheat in 1980 and 1990 will still be used primarily as a source of energy. High protein feed wheats will be desired, but their demand and use will be dictated by economics--the price, quality, and quantity of protein per unit fed versus price and nutritional value of protein supplements. Wheats high in amino acids, methionine, and lysine, will be desired particularly for the poultry industry.

Limited research has been conducted on desired grain texture and gluten characteristics for feed wheats. Earlier studies (2) indicated a soft wheat was superior to a hard wheat in feedlot studies. Ruminants fed wheat with weak gluten properties had a greater feedlot performance and nitrogen retention than ruminants fed wheats with strong gluten properties. However, Dr. Brethour reported this morning that hard wheat with strong gluten was superior to soft wheat with weak gluten.

Virtually, no research has been reported on methods of marketing feed wheats. Merchandisers have asked that feed wheats be readily identifiable from bread wheats. Color has been suggested as means of identification.

Agronomic Characteristics of Feed Wheats

The bread and feed wheats of 1980 and 1990 will be high yielding, short, stiff-strawed for resistance to lodging, and resistant to the major economic diseases. They will be highly responsive to fertilizer, especially the utilization of nitrogen for producing forage and grain with increased quantity and quality of protein.

These high yielding feed and bread wheats of 1980 and 1990 will have larger heads, more seeds per spikelet, and larger seed than varieties currently grown. Various wheats are now being used as parents which transmit larger heads with an increased number of spikelets per head. Such wheats are illustrated in figure 1. There are other wheats that have a strong tendency to transmit a multiflorous condition to the head and result in more seeds per spikelet, but not necessarily more spikelets per head. New experimental lines of winter wheats produced from such parents are presented in figure 2. Crosses are now being made to experimentally produce wheats which will produce more spikelets per head and have the multiflorous character for more seeds per spikelet.

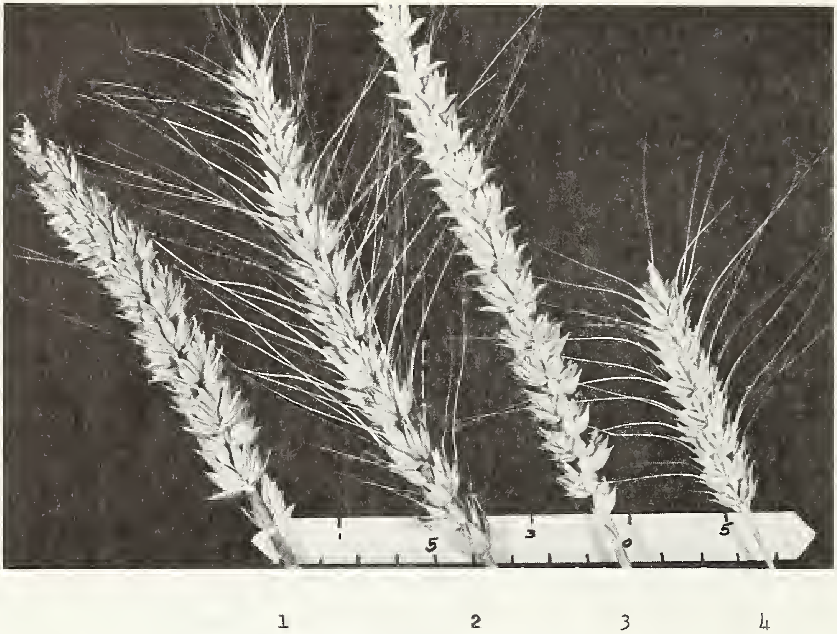


Figure 1.--Heads 1, 2, and 3 illustrate wheats with large heads and increased number of spikelets per head. Head 4 is a typical head of a Hard Red Winter wheat.

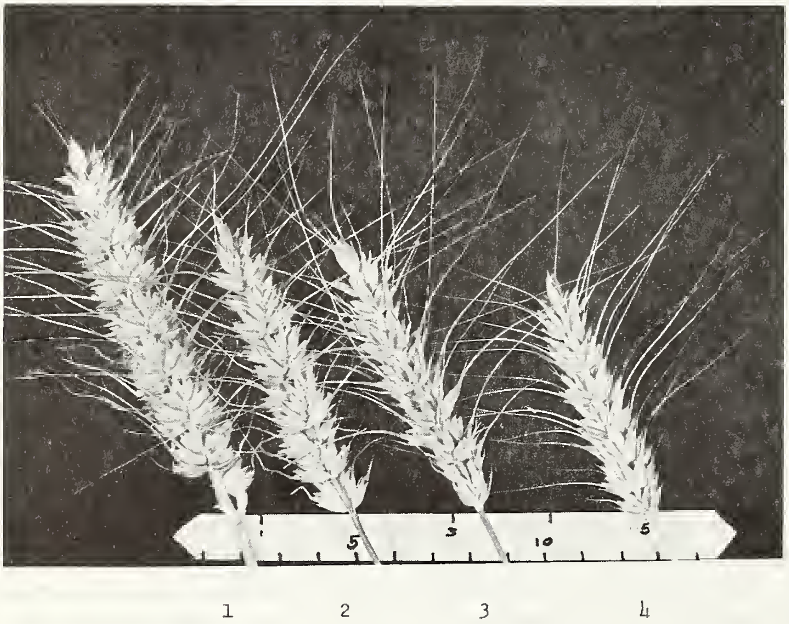


Figure 2.--Heads 1, 2, and 3 illustrate wheats with multiflorous condition which increase the number of seeds per head. Head 4 is of a typical Hard Red Winter wheat.

The third character which can contribute significantly to increased yield is seed weight. The average weight of 1,000 kernels of hard red winter wheat varies from approximately 35 to slightly over 40 grams. Vigorous screening of early generation selections for large seed has produced a few lines with significantly larger seed (fig. 3).

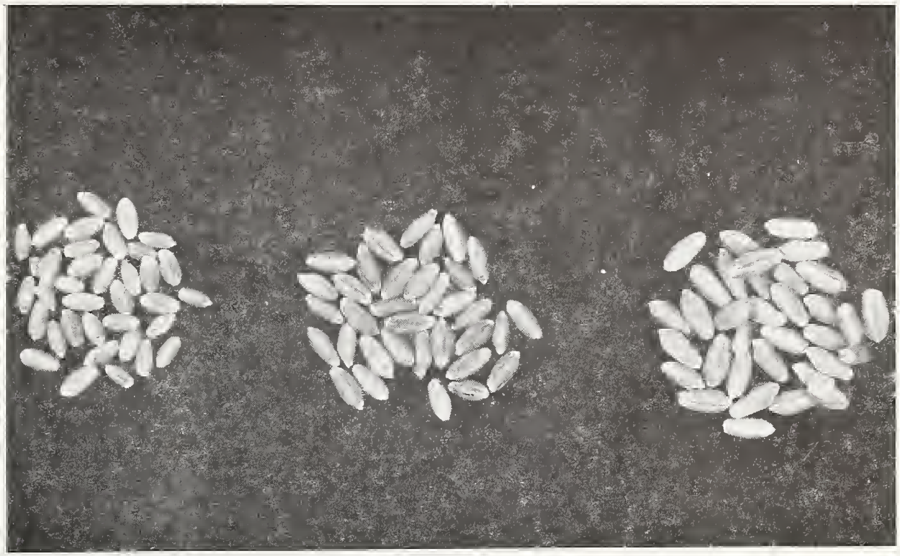


Figure 3.--Variation in seed size which can be obtained through breeding and selection. Sample 1 is an average sized seed with 1,000 kernel/weight of 40 grams. Sample 2 has a 1,000 kernel/weight of 56 grams, and the weight of sample 3 is 73 grams.

Needs of the Breeders

Increasing the yield of wheat just for the sake of higher yields would be of limited value to the overall wheat industry unless we have a potential market for this increased production. We can now produce more wheat than we can consume or export. End product usage of our wheat in domestic and export markets must be considered in our breeding programs. Should we try to compete with corn and grain sorghum in the feed industry? Can we store and market feed wheats without impairing our domestic and export markets for quality wheats and flour? If feed wheats are to be produced, what color should the grain be for identification? The answer to these questions are needed by the breeders today if we are to have the varieties to meet the future needs of the industry tomorrow.

Literature Cited

(1) Anonymous. 1969-70. International Maize and Wheat Improvement Center. Annual Report. pp. 53-113.

(2) Bris, E. J., and Dyer, I. A. 1967. New varieties of wheat for bovine finishing rations. Wash. Agr. Expt. Sta. Bul. 682.

(3) Dimler, R. J. 1969. Sixth National Conference on Wheat Utilization Research. U.S. Dept. Agr. ARS 74-54, pp. 1-19.

(4) Reitz, L. P. 1970. Opportunities and obstacles in wheat production and improvement. International Symposium Wheat in Livestock and Poultry Feeds. pp. 7-33.

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EFFECT OF VARIETY AND PROCESSING ON WHEAT AND TRITICALE PROTEINS

By J. S. Wall, J. A. Bietz, F. R. Huebner, R. A. Anderson, and A. C. Stringfellow, Northern Regional Research Laboratory, Agricultural Research Service, United States Department of Agriculture

Introduction

Exciting developments are occurring in the crops in the wheat-growing areas of the United States and other parts of the world. High-yielding, semidwarf wheats are gaining acceptance; a highly productive new grain, triticale, is being explored by many growers; and hybrid wheats lurk about the corner. The genetic materials used in development of these grain types have introduced variations in grain composition and properties that may influence current usages and encourage new forms of consumption. Milling products, baking quality, and nutritional value are related to the nature and quantities of proteins in the grains. Using new techniques of protein analysis, we have explored some changes that genetic manipulations introduce into proteins of wheat and other grains. We are seeking to associate differences in protein structure and composition to properties of the flours. Also, investigators at the Northern Laboratory are examining how readily the new grain varieties are milled to give desired products. They have demonstrated that high-protein concentrates, useful in food applications, and low-protein starch fractions can be obtained by milling triticale as well as some wheat varieties.

Chromosome Complements

The manner in which amino acids are linked together to form individual proteins is regulated by separate genes. The complexity of the chromosome complement of wheat cells is shown in figure 1. Unlike the cells of diploid rye, *Secale cereale*, which has only seven pairs of different chromosomes, ordinary bread wheat, *Triticum aestivum*, has 42 chromosomes. *T. aestivum* is considered hexaploid, as cytogeneticists have shown that these wheat chromosomes may be arranged into three sets of seven pairs of chromosomes (12). Each of these sets is designated a genome, A, B, or D. The homoeologous chromosome pairs, numbered similarly in each genome, regulate the same functions and their comparable genes are usually interchangeable. Slight differences in the genes of homoeologous chromosome result in synthesis of different proteins. Durum wheats are tetraploid and lack the D genome. Evidence for the essential role of the D genome in baking quality was obtained by Kerber and Tipples (9), who by breeding eliminated the D genome chromosomes from a baking wheat and observed that the new wheat had durum-like properties. Chromosomes of the other genomes are known also to contribute significantly to dough making and baking properties of the hexaploid bread wheats.

The seven pairs of chromosomes of rye are homoeologous to the corresponding pairs of each genome in wheat. As shown in figure 1, A and B genomes of durum wheat were combined with the rye chromosomes to yield a unique grain genus, *Triticale* (11). Some commercial varieties of triticale have undergone several generations of selection and crossing. The variety, FasGro 204, which we studied, had been obtained from crosses of triticale with hexaploid wheats. Considerable differences occur among many current triticale varieties.

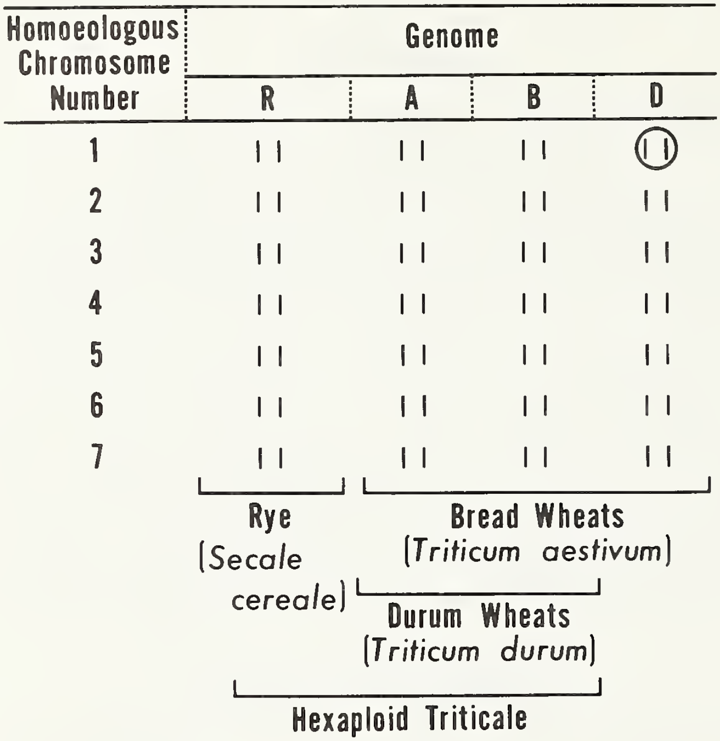


Figure 1.--Chromosomes of wheats, rye, and triticale.

Classes of Wheat Proteins

Figure 2 compares the classes of proteins which we have considered in our investigations. They may be separated by differences in solubility in various extractants or by molecular size during gel filtration.

First are the proteins soluble in water and salt solutions, the albumins and globulins. They are rich in charged amino acids, have free sulfhydryl groups, and are nutritively superior to other wheat proteins. Their molecules are highly folded and globular.

Next are the gliadins which are soluble in 70 percent ethanol solution. These proteins are low in content of charged amino acids and consist mainly of single chains of amino acids.

Another important group of proteins are the glutenins which can be dissolved in acetic acid. These molecules consist of amino acid chains linked by sulfur atoms of the amino acid cystine. They may thus form very high molecular weight polymers and are probably elongated.

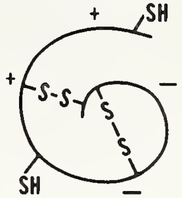
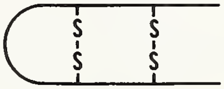
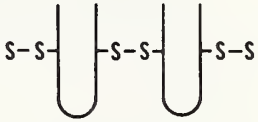
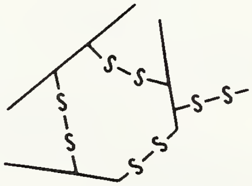
Class	Solubility	Features
Albumins and Globulins	Salt Solutions	
Gliadin	70% Alcohol Solution	
Glutenin	1% Acetic Acid	
Residue	Reducing Agents or Alkali	

Figure 2.--Types of proteins in wheat flour.

And finally, we are left with insoluble or alkali-soluble proteins in the flour which are not yet fully characterized. There is evidence they are linked by extensive disulfide bonds, since much of the protein is solubilized by reducing agents. Some of this protein may be associated with carbohydrate or may be combined with lipid. Much work needs to be done to clarify their structures.

All classes of proteins play a role in grain structure and dough properties. The water-insoluble glutenin and gliadin are the major components of wheat gluten. Variations not only in total protein, but also in the relative amounts of different protein classes are responsible for some differences in functional properties of flours from different wheats. Table 1 compares the amounts of the different classes of proteins in flours from wheats and other grains. The data are a composite of results obtained in our Laboratory by different isolation methods. Similar protein extraction results on some of the same hard wheats have also been reported by Sinha and coworkers (15) while extraction yields of proteins from rye, triticale, and wheats have been determined by Chen and Bushuk (4). The list of grains in table 1 is arranged so that those that produce the strongest doughs and yield the toughest glutens are towards the top of the table. The strong wheats yield the least quantities of albumins and globulins and the greater amounts of glutenins and acetic acid-insoluble proteins. For example, the long mixing requirement for the hard red spring, Semidwarf Red River 68, is associated with its higher content of glutenin and insoluble proteins compared with the hard red winter wheat, Ponca, which has a normal mixing time. Finney and others (6) have shown that reducing agents, such as cysteine, will lower the mixing requirements for Red River 68, indicating that mixing time is related to excessive disulfide crosslinks in the protein. The high mixing requirement of Red River 68 is inherited from one of its parent varieties and is not characteristic of many semidwarfs.

Table 1.--Distribution of protein classes in wheats and other grains based on gel filtration separation

Type	Variety	Flour protein	Acetic acid soluble: Albumin and globulins	Acetic acid soluble: Gliadin	Acetic acid soluble: Glutenins	Acetic acid insoluble
		Percent	Percent of flour protein			
Hard red spring semidwarf	Red River 68	12.7	12	25	25	33
Hard red winter	Ponca	10.7	15	29	27	22
Soft white winter	Brevor	9.5	17	26	24	25
Durum	Lakota	15.4	15	33	20	23
Triticale	FasGro	12.7	25	22	25	19
Rye	---	10.9	35	15	20	20

Rye and triticale, of course, form only very weak glutens. Their protein contains a high level of salt solubles, small amounts of gliadin component, and little insoluble protein. The high levels of water solubles contribute to the lysine content and nutritional superiority of these grains (4). Unfortunately, rye and triticale flours alone make breads with poorer loaf characteristics than bread wheats (11).

Varietal Differences in Glutenin Structure

While all of the protein classes contribute to properties of the flour, the cohesive elastic nature of dough and gluten is primarily a property of the hydrated glutenin protein. In addition to differences due to amounts of glutenin proteins, mixing characteristics of flours appear related to the nature of the glutenins. Huebner (7) found that the solubility of glutenin proteins in the presence of salt varied in a manner related to the quality of wheat flour for baking. As shown in figure 3, when increasing levels of salt were added to urea-acetic acid solutions of glutenin, turbidity developed due to precipitation of the protein. Glutenin from the hard red spring wheat, Selkirk, was salted out before that of the hard red winter wheat, Comanche; but glutenins from both these wheats were salted out before that of the poor baking Red Chief. The mixing characteristics of doughs are related to the tendency of glutenin molecules to adhere together, which can be measured by their insolubility in the presence of salt.

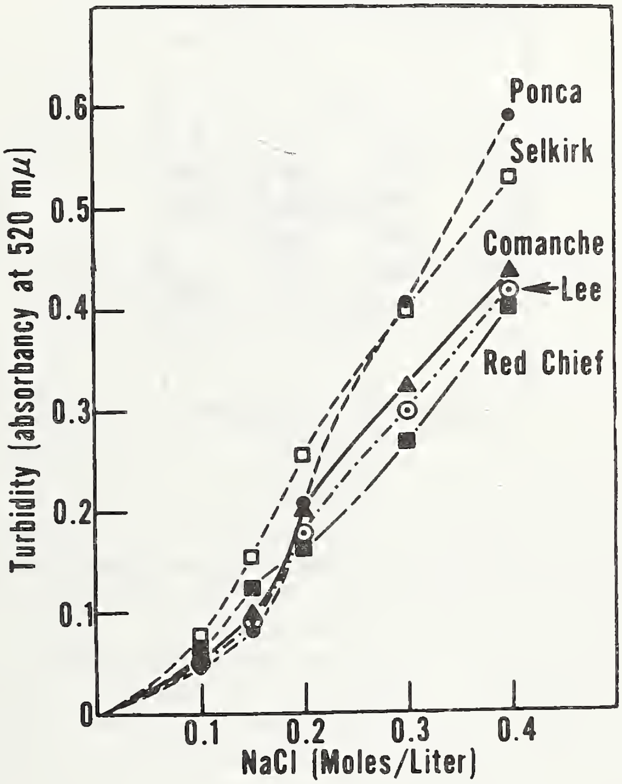


Figure 3.--Effect of sodium chloride concentration on solubility of glutenins dissolved in 2 M urea:0.03 M acetic acid.

In further studies we gained evidence that the glutenins of wheat varieties differing in mixing time may also differ in degree of molecular aggregation or size. To demonstrate size differences in glutenin molecules, we employed gel filtration on columns of agarose (8). The principle of this process is diagrammed in figure 4. A gel consisting of porous polysaccharide beads is placed in a tube to form a column. When a solution containing protein molecules of different sizes is passed through the column, the smaller molecules enter the gel pores and are retarded. The larger molecules can enter fewer pores and elute more rapidly from the column.

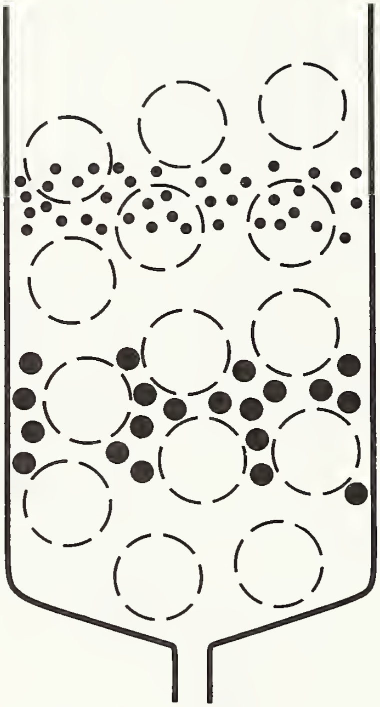


Figure 4.--Principle of gel filtration chromatography on agarose columns.

In figure 5 the rates of elution of three different glutenins from agarose columns are compared. Semidwarf Red River 68 glutenin eluted earliest in a sharp peak. Hard red winter Ponca glutenin was next, while Brevor, a soft white winter wheat, yielded a glutenin that eluted last and over a greater volume. Evidently, in this solvent Red River 68 glutenin exhibits the highest molecular weight distribution and that of Brevor the least. This relationship between the glutenin molecular weights is consistent with mixing times for formation of doughs from the different flours. It would appear that the larger the glutenin molecular aggregates, the tougher the dough.

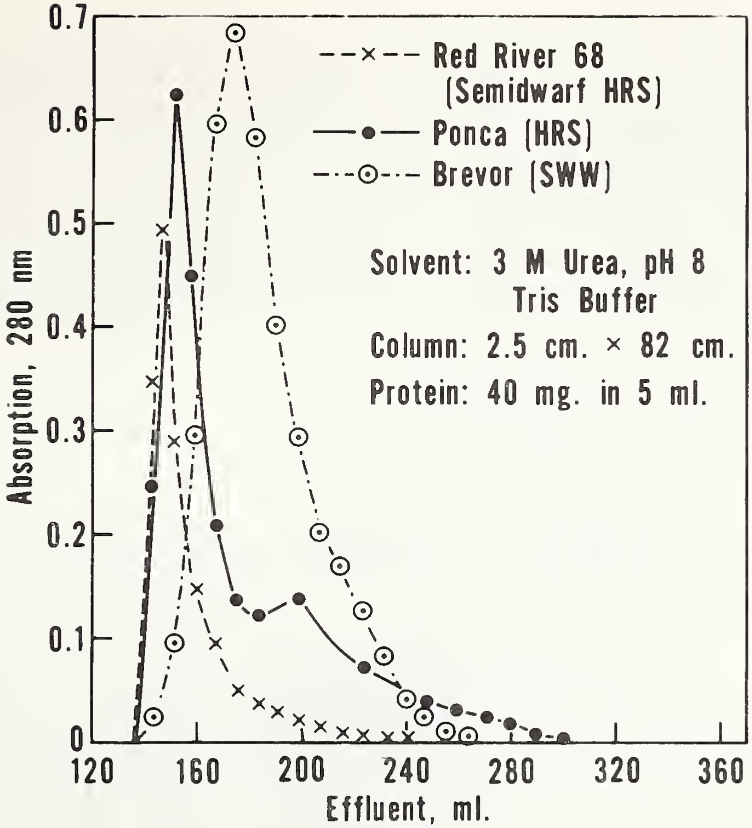


Figure 5.--Chromatography of glutenins isolated from different wheat varieties on agarose columns.

Subunit Composition of Glutenins

What is the basis for the difference in molecular properties of glutenin proteins from different varieties? As shown in figure 6, glutenin can be reacted with chemical reducing agents to break its disulfide bonds and release its component subunits. Recent studies with gel filtration demonstrated that the subunits differ in size and other properties, including amino acid composition (5). Differences in subunits among glutenins from different varieties may be keys to variation in their physical properties.

To separate the subunits of glutenin and to determine differences in their sizes and amounts, we have used a new technique, polyacrylamide gel electrophoresis, in media containing the detergent, sodium dodecyl sulfate (SDS) (16). Figure 7 shows that after disulfide bonds of proteins are cleaved SDS combines with the unfolded protein. The SDS-protein complex assumes a stiff rod shape, and the negative charges on the detergent mask the charges on the protein. As shown in figure 8, the SDS protein complexes, after insertion into polyacrylamide gels, migrated under the influence of an electric potential towards the positive anode. Unlike in ordinary electrophoresis, the rate of migration is proportional to molecular weight of the original proteins. This conclusion is verified by the distances from the origin of two series of proteins of known molecular weights used as standards in figure 8. Bietz and Wall (3) demonstrated (fig. 8) that gliadin proteins contain subunits primarily of molecular weight 34,000, but lesser amounts of polypeptide chains of 44,000 and 11,000 molecular weights are also present in reduced gliadin proteins. In contrast, reduced glutenin consists of a large number of protein species, at least 15 different components varying in molecular weight from 11,000 to 133,000. A major component of glutenin has a molecular weight like that of the 44,000 molecular weight component of gliadin.

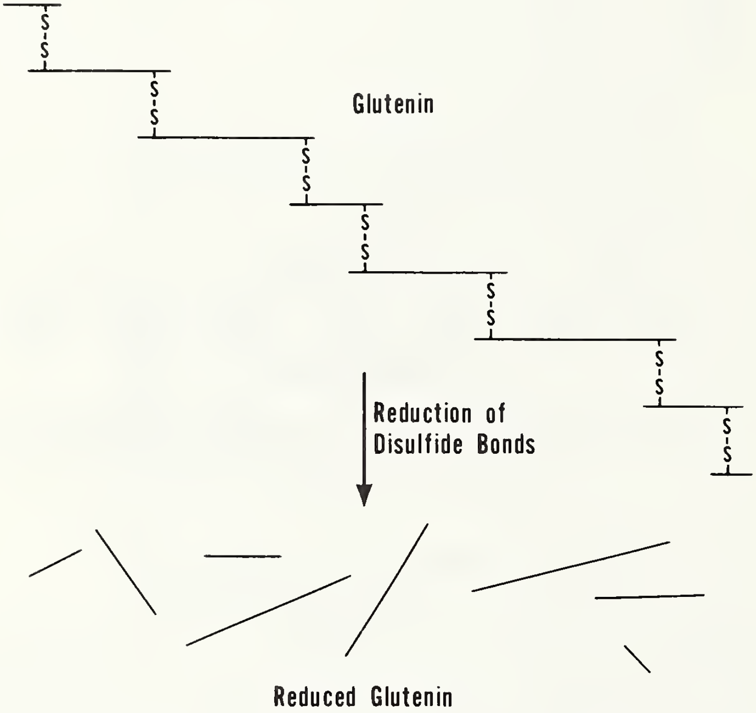
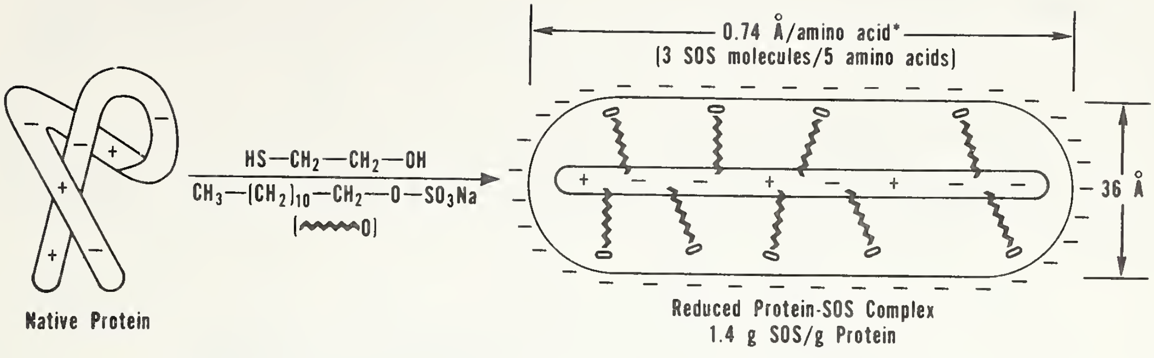


Figure 6.--Cleavage of disulfide bonds in glutenin protein by reducing agents.



* Reynolds and Tanford, J. Biol. Chem. 245: 5161 (1970).

Figure 7.--Principle of polyacrylamide electrophoresis with the detergent, sodium dodecyl sulfate (SDS).

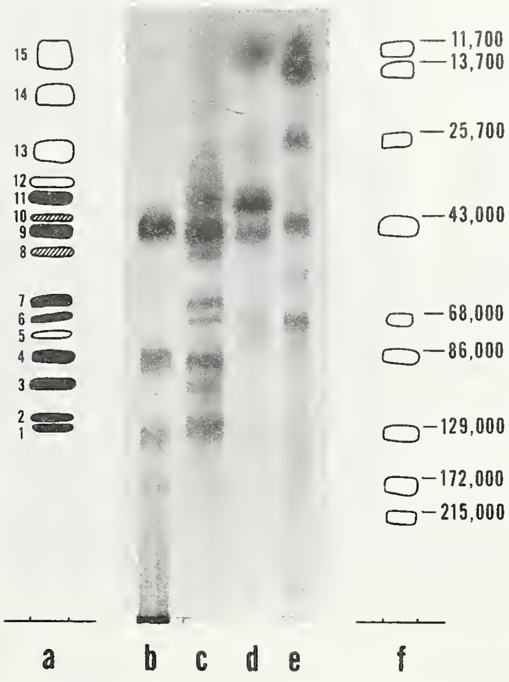


Figure 8.--SDS electrophoresis patterns for determination of molecular weights of gliadins and glutenins by comparison of mobilities to that of known proteins. (a) Diagram and numbering system used in text for glutenin subunits, with prominent bands shaded; (b) polymeric ovalbumin; (c) glutenin; (d) gliadin; (e) standard protein calibration mixture; and (f) composite diagram and molecular weight of components of calibration mixtures.

Figure 9 shows SDS-electrophoresis patterns of reduced glutenins isolated from a number of different varieties of wheats (3). The first three samples on the left are glutenins from hard red winter wheats, Ponca, Red Chief, and Comanche. We can detect quantitative differences in subunit components 6 and 7 between the poor baking Red Chief and the two satisfactory wheats. Red River 68 glutenin is especially rich in component 8, the 44,000 molecular weight protein, in contrast to glutenin from another hard red spring wheat, Selkirk. The three patterns on the right for Omar, a club wheat, and Brevor and Seneca, soft winter wheats, exhibit low levels of the high-molecular-weight bands in the lower part of the electrophoretic pattern. The Wells durum wheat is totally devoid of the highest molecular weight components 1 and 2 and component 12. These and other studies indicate that the D genome may be responsible for high-molecular-weight components which contribute unique properties to glutenins of bread wheats.

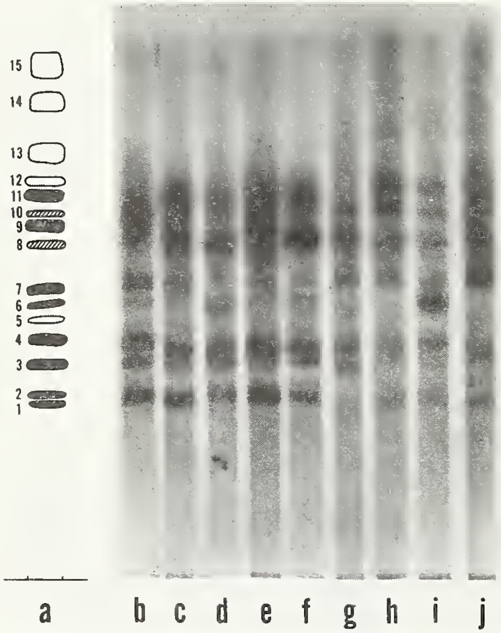
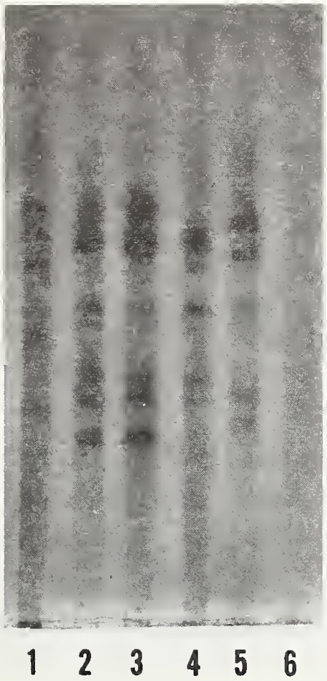


Figure 9.--Differences in subunits of glutenins from different varieties of wheat varying in baking performance by SDS electrophoresis. (a) Diagram and numbering system used in text for Ponca glutenin subunits, with prominent bands shaded; (b) Ponca /hard red winter (HRW)/; (c) Red Chief (HRW); (d) Comanche (HRW); (e) Selkirk /hard red spring (HRS)7; (f) Red River 68 (HRS); (g) Wells (durum); (h) Omar (club); (i) Brevor (soft white winter); and (j) Seneca (soft red winter).

Because of current interest in breeding programs for improved strains of triticale, we were interested in seeing whether inheritance of glutenin protein characteristics in this grain could be examined by SDS electrophoresis. Chen and Bushuk (4) studied the chemistry of other proteins in triticale and related grains. Figure 10 shows subunits of three bread wheats, a durum wheat, triticale, and rye. The triticale pattern has glutenin components typical of rye and durum wheats, but also a high-molecular-weight band associated with bread wheats. Perhaps this latter component was introduced during crossing of the triticale with hexaploid wheats. We are presently conducting a more extensive study of rye and triticale glutenins to clarify this problem.



1 - Brevor (soft white winter)
2 - Ponca (hard red winter)
3 - Selkirk (hard red spring)
4 - Wells (durum)
5 - Triticale
6 - Rye

Figure 10.--Comparison of molecular weights of subunits of glutenins from various wheats, triticale, and rye.

Are SDS electrophoresis bands of similar molecular weight in different wheats of similar amino acid composition? What are the unique characteristics of high-molecular-weight bands missing in durum wheats? To clarify these points we are now separating and isolating the subunits of glutenin by a combination of chromatographic techniques. The acquisition of pure glutenin proteins should permit us to obtain further data on their properties and on differences among varieties.

Summary of Glutenin Studies

Results from our studies of glutenin proteins in different varieties of wheat indicate that mixing time and dough strength for flours are related to:

1. Amount of glutenin protein
2. Molecular weight of glutenin
3. Subunits of glutenin

Wet Milling of Wheat and Triticale Flours

Not only do the proteins of wheat influence baking properties of the flour, but they also affect the milling characteristics and the nature of the milled products. With growing interest both domestically and abroad in protein concentrates for food uses, considerable attention has been directed to wheat and related grains as possible sources. Acceptable functional properties, flavor, and nutritional value encouraged investigations by Anderson et al. (1) of triticale gluten isolation by wet milling.

Table 2 compares the results of wet-milling experiments on triticale and earlier reported yields of products from a soft white winter wheat and a hard red spring wheat (10). A Martin-type process on a laboratory scale was used. The flour was kneaded to yield a doughball which was washed to remove the starch. Since triticale yielded a soft, weak gluten ball the dough could be worked only with care. Despite the poor gluten strength, the recovery of protein in the gluten was comparable with that from the wheat flours. The triticale gluten was unsatisfactory when compared with hard red spring wheat gluten as an additive for baking performance improvement of low protein flours. However, the superior lysine content, softer character, and bland flavor offer interesting opportunities for its use in food applications. Growing requirements in preprepared foods for fat emulsifiers, water-absorbing and component-binding agents, and nutritive supplements should offer potential markets for use of glutens from wheat as well as from triticale.

Further encouragement for industrial wet milling of triticale flours is based on the high yield, 69 percent, of low-protein starch (table 2). The higher yields of grain claimed for triticale crops compared with those of wheat would indicate lower cost starch production from triticale. Triticale starch has been shown by Berry et al. (2) to have suitable properties for many food and industrial uses.

Air Classification of Wheat and Triticale Flours

Another process whereby protein-rich fractions can be isolated from cereal flours is air classification (13). Genetic variances in grain structure and in protein content and composition greatly influence the response of wheat, rye, and triticale flours to milling and air classification.

Table 2.--Yields of wet milling fractions from various flours
(Percent, dry basis)

Item	Triticale	Soft winter wheat	Hard red spring wheat
Flour protein	14.7	14.2	16.4
Gluten yield from flour	17.0	14.0	17.8
Protein in gluten	70	80	78
Flour protein recovered in gluten	81	80	84
Lysine in gluten protein	2.3	1.9	1.6
Starch yield from flour	69	71	70
Protein in starch	0.4	0.4	0.3

To facilitate air classification, flour particles first must be finely ground. This was accomplished by passing the flours three times through a pin mill. The basic principle of air classification is diagrammed in figure 11. The flour particles impinge on a rotating plate. A stream of air deflects the particles into fractions differing in size and density. In these experiments a Pillsbury Laboratory Model Air Classifier was used to separate the flour into a coarse and a fine fraction. By readjusting the classifier for a coarser cut and reclassifying the coarse fraction, seven fine and one coarse fractions were obtained.

Results obtained by our Engineering and Development Laboratory (1) of air classification of flours from triticale, rye, and wheat are compared in table 3. The initial flours differed in protein content. All of the flours from the different grains showed increased protein in the air-classified fractions of smaller particle size, 1-3. For triticale a good yield of protein-enriched fractions (25.1 percent) was obtained, with 29 percent average protein content as compared with the original 12.7 percent protein in the flour. This protein content was the highest for all the flours subjected to air classification even though the initial durum flour was higher in protein. The hard red winter wheat gave a better yield and concentration of protein in the high-protein fractions than the higher protein hard red spring wheat.

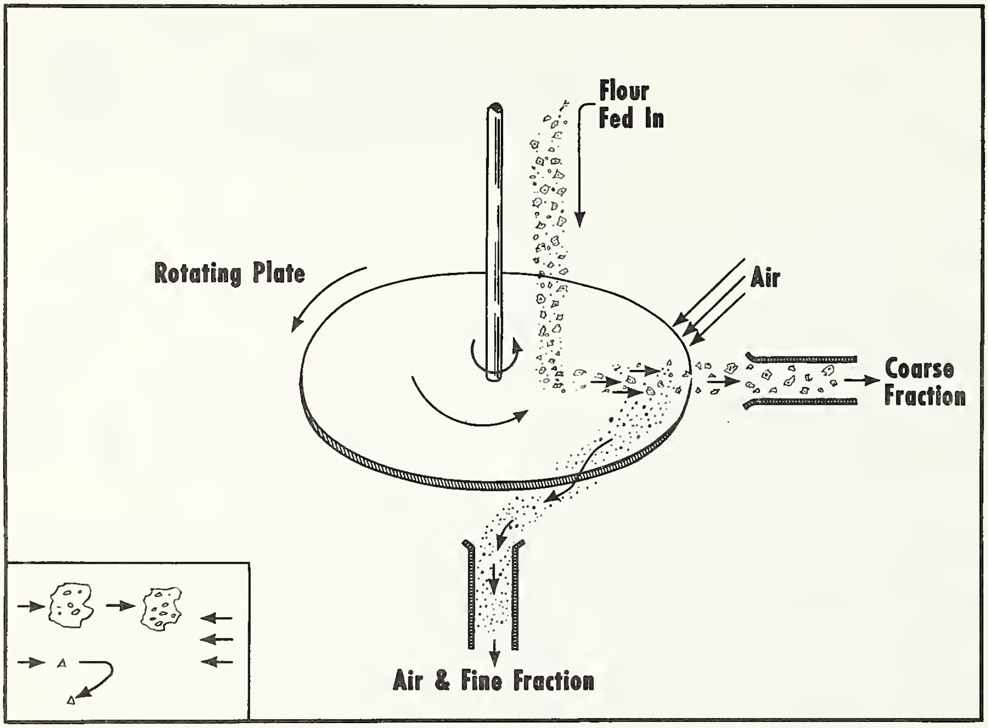


Figure 11.--Principles of air classification of cereal flours.

For triticale the combined starchy fractions, 4-7, amounted to about 65 percent of the initial flour and had an average protein content of 5.5 percent (table 3). These fractions were higher in protein than those from rye or soft wheats (14) but are low enough in protein to have industrial potential. The harder wheats, especially durum, gave poor recoveries of starchy fractions which exhibited less reduction in protein contents. The yield of coarse residue was especially low for triticale, emphasizing that its kernel structure was especially adaptable for fine grinding (table 3).

The significant new observation made in these studies is that the protein shift--a measure of the ability to concentrate protein in certain fractions--was very high for triticale (73 percent), almost as good as for soft wheats (14) and superior to rye and the wheats listed in table 3. This high protein shift is especially promising, considering the high protein content and protein quality of triticale for food uses. Evidently the soft character of the grain of this variety of triticale, FasGro 204, was especially conducive to good milling and air classification. As other varieties of triticale become available in quantity, they also should be examined for milling and air classification potential.

Table 3.--Comparison of fractionation responses of reground flours from triticale, rye, and wheat (14 percent moisture basis)

Item	Triticale	Rye	Wheat		
			Durum	Hard red spring	Hard red winter
	FasGro 204	Balboa	Wells	Selkirk	Wichita
Straight flour					
Protein, percent	12.7	8.2	15.7	12.8	10.9
Combined high-protein fractions (1-3)					
Protein, percent	29.0	15.9	23.6	19.4	24.4
Yield, percent	25.1	26.8	9.2	18.8	21.0
Combined starchy fractions (4-7)					
Protein, percent	5.5	4.8	12.0	8.7	6.5
Yield, percent	65.3	60.4	30.3	49.5	52.9
Coarse residue fraction (8)					
Protein, percent	13.3	5.2	16.4	14.2	9.8
Yield, percent	9.6	12.8	42.2	31.7	26.1
Protein shifted, total percent	73	50	15	29	50

Summary of Wet Milling and Air Classification Studies

The observation from the limited wet-milling studies is that while wheats yield a superior quality gluten for use as a baking supplement, triticale offers an economic high-yielding source of more nutritious protein and a potentially cheaper source of starch.

Air classification in wheats is adversely affected by grain hardness and protein content. In contrast, the soft kernels of a triticale variety of high protein content gave a good yield of enriched (29 percent) protein fraction and of low protein starchy fractions, both with commercial potentials.

General Conclusions

Recent developments in new wheat varieties and triticale have demonstrated that wide variations in protein content and composition can be introduced by genetic manipulations. These variations result in important modifications in dough behavior and milling response. Systematic studies of these variations may make it possible to breed grains to specific quality specifications for designated uses.

Literature Cited

(1) Anderson, R. A., Stringfellow, A. C., and Griffin, E. L., Jr. Triticale: Preliminary processing studies. Northwest. Miller (in press).

(2) Berry, C. P., D'Appolonia, B. L., and Gilles, K. A. Characterization of triticale starch and its comparison with starches of rye, durum, and HRS wheat. Cereal Chem. 48:415-427. 1971.

(3) Bietz, J. A., and Wall, J. S. Wheat gluten subunits: Molecular weights determined by sodium dodecyl sulfate-polyacrylamide gel electrophoresis. Abstract 136, 56th Annual Meeting, American Association of Cereal Chemists, Dallas, Tex., October 10-14, 1971. 1971.

(4) Chen, C. H., and Bushuk, W. Nature of proteins in _triticale_ and its parental species. I. Solubility characteristics and amino acid composition of endosperm proteins. Can. J. Plant Sci. 50:9-14. 1970.

(5) Crow, M. J. A., and Rothfus, J. A. Chromatography of proteins from wheat gluten on polyacrylamide gel. Cereal Chem. 45:413-420. 1968.

(6) Finney, K. F., Tsen, C. C., and Shogren, M. D. Effect of cysteine on mixing time, water absorption, oxidation requirement and loaf volume of Red River 68. Abstract 49, 55th Annual Meeting, American Association of Cereal Chemists, Minneapolis, Minn., October 18-22. 1970.

(7) Huebner, F. R. Comparative studies on glutenins from different classes of wheat. J. Agr. Food Chem. 18:256-259. 1970.

(8) Huebner, F. R., and Rothfus, J. A. Evidence for glutenin in wheat: Stability toward dissociating forces. Cereal Chem. (in press).

(9) Kerber, E. R., and Tipples, K. H. Effects of the D genome on the milling and baking properties of wheat. Can. J. Plant Sci. 49: 255-263. 1969.

(10) Knight, J. W. Chemistry of wheat starch and gluten and their conversion products. Leonard Hill, London, pp. 24-25. 1956.

(11) Larter, E. Tsuchiya, T., and Evans, L. Breeding and cytology of _triticale_. Third International Wheat Genetics Symposium, Plenum Press, New York. 1968.

(12) Morris, Rosalind, and Sears, E. R. The cytogenetics of wheat and its relatives. Wheat and wheat improvement. American Society of Agronomy, Inc., Madison, Wis. 1967.

(13) Peplinski, A. J., Stringfellow, A. C., and Griffin, E. L., Jr. Air classification of durum and hard red spring wheat flours. Northwest. Miller 272(5):34, 36-37. 1965.

(14) Peplinski, A. J., Stringfellow, A. C., and Griffin, E. L., Jr. Air classification of Indiana, Ohio, and Michigan soft wheat flours. Northwest. Miller 271(2):10-12. 1964.

(15) Sinha, S. S., McDonald, C. E., and Gilles, K. A. Studies on proteins of semidwarf wheats. Abstract 53, 55th Annual Meeting, American Association of Cereal Chemists, Minneapolis, Minn., October 18-22, 1970.

(16) Weber, K., and Osborn, M. The reliability of molecular weight determinations by dodecyl sulfate-polyacrylamide gel electrophoresis. J. Biol. Chem. 244:4406-4412. 1969.

ECONOMIC OUTLOOK FOR WHEAT

By Clifford G. Pulvermacher, Export Marketing Service, United States Department of Agriculture

For the past 6 years, the world's wheat producers and trade have been on a virtual roller coaster. As recently as 1967, we were in an extremely tight wheat situation that caused dire predictions of world hunger and even famine. The United States and other major suppliers stepped up production sharply to meet the demand. Shortly thereafter, the full impact of the Green Revolution began to hit the major food deficit countries. The result was 2 years of record world wheat production, fierce world competition, and depressed world prices.

The 1970 crop year brought another abrupt change. Canada adopted a land retirement program that cut its wheat production in half. Australia had an average crop, but it was low in protein. Both Western and Eastern Europe had short crops, and the U.S.S.R., although its crop was good, did substantial importing from Canada's big supply. Our corn blight problem and feed grain shortages elsewhere brought a strong demand for wheat as feed.

All these factors led to an excellent wheat export year for the United States in 1970-71. We shipped a total of nearly 740 million bushels of wheat and wheat products, valued at $1.2 billion, up more than 20 percent from the previous year. It was the third best wheat export year in our history. Our commercial exports were the highest ever.

Japan was, as usual, our best customer, and for the first time purchased more than 100 million bushels for the year. This is a goal to which we aspired for many years. It represented more than 60 percent of the foreign wheat purchased by Japan during its fiscal year, up from 52 percent the previous year.

It was my pleasure to represent Secretary of Agriculture Hardin at a ceremony in Tokyo last spring in observance of this achievement, which was brought about by teamwork on the part of the Governments of Japan and the United States, and industrial groups in both countries.

It was a good year for nearly all of our classes of wheat. Hard Red Winter was the big gainer, up 42 percent from the previous year. Hard Red Spring was up 27 percent, and Durum 13 percent. Only White Wheat and Soft Red Winter showed slight declines, and in the case of White Wheat this was because stocks of this wheat were exhausted by crop-year's end.

This fall, however, we are facing a considerably different situation. As I am sure you all know, our 1971 crop is estimated at an all-time high of 1.6 billion bushels, with acreage somewhat higher than in the two previous years and the average yield indicated at an all-time high of 33.6 bushels.

Canada's 1971 acreage was up 56 percent, indicating a return to approximately three-fourths of normal in that country, which still has a carry-over equal to a 2-year export supply. Australia and Argentina are just harvesting their 1971 crops, but both are expected to be up from the reduced levels of last year. Western Europe's 1971 crop is probably a new record high. Indications point to another good crop in the Soviet Union.

Sales of feed wheat from the United States, especially to the United Kingdom, are likely to be sharply reduced this season. This is partly because of better weather and higher price guarantees in the United Kingdom, which have brought a larger crop, and partly because of greatly increased competition from the large crop in the common market countries, and the anticipation of larger export subsidies to move it.

One of the important economic trends in today's wheat world is the increased use of wheat for feed, particularly in Western Europe. It is estimated that over 30 percent of the grain fed in the United Kingdom is wheat, and nearly 20 percent in the common market countries. Unfortunately, U.S. growers do not stand to benefit much from this trend, except in unusual short crop situations such as the Europeans experienced last year. Normally, feed wheat used by European farmers is produced in their own countries. Moreover, it has a tendency to replace imports of feed grains, particularly U.S. corn.

As a result of the Green Revolution, we no longer have the large PL-480 markets that at one time took more than half our wheat exports and at the peak nearly 40 percent of a year's crop. India has another record crop and has stated it expects to import no wheat under PL-480 after December 31 of this year. Turkey has its largest crop in almost 20 years.

It is difficult to forecast how much more PL-480 wheat Pakistan will need to feed victims of its civil strife, and how much more India will need to feed Pakistani refugees. We have already furnished well over a million metric tons of wheat under Titles I and II of PL-480 to meet needs resulting from the 1970 Pakistan cyclone and the 1971 civil strike, and it is likely that substantially more will be needed.

One factor that is impossible to weigh at this time is the series of work stoppages on docks in the Pacific Coast, Eastern, and some Gulf ports. The extent to which we are hurt depends on the duration of the strikes, but we have certainly lost a great deal of business that will never be made up. Australia, for example, has moved substantial quantities of soft wheat to Japan, Korea, and other Far Eastern destinations while our pipeline for Western White has been backed up from the dock to the elevator to the farm.

Another imponderable is the effect of the President's rescission of the requirement that 50 percent of sales of wheat and wheat products to Eastern Europe and the Soviet Union be shipped on U.S. flag vessels. That action will certainly improve our competitive position in this region, but the Soviet Union, in addition to having a good 1971 crop, has already made large purchases from Canada for delivery through 1972.

In the face of the many uncertainties and the sharp competition we face, we are making the CCC Credit and Barter Programs available to the maximum extent to help in supplementing cash exports. Last year, these two programs combined accounted for almost 25 percent of our total wheat exports, or about one-third of our commercial sales.

The President's action in "floating" the dollar should be a strong force in lowering the cost of our agricultural exports to our foreign customers. As of mid-October, it had lowered our prices to West Germany by more than 10 percent, to Japan by almost 9 percent, and to the Netherlands and Canada by more than 7 percent.

Wheat producers have unfortunately not realized the benefits of expanded wheat exports from the improved price relationships of U.S. wheats to other wheats in the world markets because of the crippling effects of the prolonged dock strikes and work stoppages upon our wheat exports. These are hurting us in the world wheat markets, and hurting us seriously. If this problem is not resolved soon, some of the damage done to our position in the world wheat markets will be irretrievable.

Canada and Australia are making full use of our impaired position by moving their wheat in ever-increasing quantities into markets in which we worked very hard over many years to develop for U.S. wheats. Australia is expecting an all-time record wheat export year and Canada already has almost 100 percent of its grain export capacity committed through July 31. To give away export markets to our competitors, which took so many years to develop because U.S. labor and management are unable to come to a settlement of the dock strikes, is to say the least, most unfortunate. We believe that the President's economic program will serve as a definite stimulus to grain exports when our U.S. port situation returns to normal.

Adding up the pluses and the minuses, it is hard to see how we can avoid some reduction in our wheat exports this year from last year's level. Currently, the Department is estimating 1971-72 wheat and wheat product exports at about 600 million bushels or slightly higher, about the same level as in 1969-70.

For the short-term future, our people in the Department do not foresee much change in the situation. In other words, we are likely for several years to have abundant supplies in major exporting countries, a slow-up in the growth in import demand, continuing pressure on prices, and keen competition for markets. Food aid requirements will probably continue to drop slightly.

There are, certainly, some bright spots in the picture. One is the continued strength of the Japanese economy and its mounting wheat purchases. We have been supplying half or more of that growing market for the past 5 years and must make every effort to hold or increase that share.

One of the great virtues of Japan as a market is that it takes almost the full range of our wheat classes. Japan's biggest gain in wheat flour use during the past decade has been for bread, which now accounts for about one-third of all the wheat flour it consumes. This development has enabled the United States to increase its sales of higher protein hard wheats to Japan. Increased sales of Hard Red Spring have been particularly notable.

The fastest growing outlets for flour in Japan are confectionery, industrial, and home use, which require mostly soft and semihard wheats. This has opened up new outlets for Western White and Hard Red Winter of lower protein content.

Now we are developing a Japanese market for Durum wheat for pasta production. Our Durum sales to Japan reached nearly 2 million bushels last year, and prospects for further growth are good.

Currently, our trade with Japan is hampered not only by the dock strike but by such economic differences as currency reevaluation or devaluation, our import surcharge, and our policy on textile imports. Early settlement of such differences is vital to wheat growers, who have come to depend on Japan for about 1 in every 7 bushels of wheat they export.

Also, on the positive side is the development of numerous smaller markets in all parts of the world. Korea last year replaced India as our No. 2 wheat outlet, part of it PL-480 business and part commercial. Taiwan, a growing cash market, has contracted with Australia for much of its 1971-72 needs because of our dock strikes. Hong Kong is another growing dollar market in the Far East.

There is some growth in the wheat markets of the Middle East, where we have traditionally supplied about 50 percent of the imports. We also have considerable market potential in the countries of Latin America, Central America, and the Caribbean. Individually, these latter markets are small, but collectively they took well over 1 million tons of our wheat and wheat products last year.

Another bright spot is the excellent showing of our Spring and Durum wheats in the export market. Both these wheats have established a fine reputation for quality in foreign markets thanks to years of hard work by producers, marketing officials, cereal technologists, grain trading firms,and others. This past season, we exported more than half of our 1970 Spring wheat crop and more than 75 percent of the previous year's Durum crop.

It would be idle for me to speculate on the effect of U.S. wheat and other agricultural exports of the President's action in terminating controls on nonstrategic exports to Mainland China. China has been importing from 100 to 200 million bushels of wheat annually for the past 10 years. Much of this business has gone to Canada, which has announced contracts to deliver 118 million bushels of wheat to the Chinese in calendar 1971. These contracts call for a 25 percent down payment in cash with the balance payable with interest in 18 months. At this time we have no indication that we may do wheat business with China in the near future, but we do not foreclose the opportunities which may later develop.

The expansion of export markets for U.S. wheat is a key ingredient to assuring wheat producers a fair return for their product. Those of us who are engaged in this effort will do all we can to make this possible. I appreciate the opportunity to visit with you about these matters, particularly on such a pleasant occasion.

TRENDS IN WHEAT PRODUCTION BY MAJOR EXPORTING COUNTRIES

By K. A. Gilles, North Dakota State University

It has been said that speeches may proceed along two major pathways, the logical and the chronological. Which pathway is the most appropriate? If we are to present a brief discussion of trends in wheat production, the chronological approach would seem to be appropriate. Moreover, I do not propose to delve into the specifics of economic data; rather to present a general pattern of trends that seem to be emerging among the major exporting nations of the world.

Of course, one would then ask, what kind of trends and with reference to what position? As one looks back in history, one could say that a considerable number of trends have developed. Among them, six major exporting nations have appeared which have substantially affected world trade in wheat. These are Russia, France, Canada, the United States, Australia, and Argentina. Of this group, Russia has appeared to present some of the most interesting trends of all. For it has gone from a major exporter, at the turn of the century, to a net importer, as recently as the early sixties, and to a point where it is occasionally an opportunistic sales exporter in current times.

Because the export pattern is so highly dependent upon the key elements such as the whims of nature, the political climate established among nations, and more specifically between the buyer and seller, I would not presume to suggest that the patterns of recent years would indicate clearly the patterns of export potential in the immediate future.

Doubtless, we are all well aware of the fact that it is not only wheat production but wheat consumption patterns which affect major exporting countries. As one surveys the world in its totality, it is very obvious that the farmers of the world currently are capable of producing far more wheat, particularly of the low protein types, than the people of the world desire to consume. Obviously, the consumption patterns are influenced greatly by problems in distribution, transportation, storage, and ethnic preference for certain types of cereal foods.

Because of adequate rainfall and favorable growing conditions for the past several years, the wheat growers of the world have produced an abundance of wheat. We, in the United States, also have enjoyed this abundance and have succeeded in producing a record wheat crop in 1971 estimated to be approximately 1.6 billion bushels. This represents about an 18 percent increase over the 1.4 billion bushels produced in the preceding year.

Historically, the United States has produced about 80 percent winter wheat, 16 percent spring, and 4 percent durum. The pattern for the 1970 crop was typical. We produced about 1.1 billion bushels of winter wheat which represented 81 percent of the total, 210 million bushels of spring wheat which represented 15 percent of the total, and 50 million bushels of durum which represented about 3.7 percent of the total. However, the pattern in 1971 has undergone a rather abrupt change. Total production of spring and durum wheat has advanced markedly, and the pattern of distribution of wheat classes this year is approximately 71 percent winter wheat (1.2 billion bushel), 23 percent spring wheat (376 million bushels), and 5 percent durum (87 million bushels). Fortunately, because of good weather conditions, the general quality of this year's crop is considered good. The protein content of the winter wheats of the Southern Great Plains is about 1 percent above the 5-year average; whereas, the protein content of spring wheats is about 1 percent below the 5-year average. Consequently, we will doubtless see some shifts in utilization in the domestic market because the need for the higher protein, stronger types of spring wheats will probably be less in the 1971 crop year than it has been for the past several years.

Types of Wheat

Semidwarf

In the domestic market, there has been a trend to explore and utilize a number of the derivatives of the Green Revolution. The semidwarf type of wheats, which have received considerable publicity in Mexico and a number of the less developed nations of the world, have been designed to utilize relatively high levels of fertilization when adequate water is provided; usually this provision is made by means of irrigation. These semidwarf wheats have been utilized in commercial production in California, the Pacific Northwest, the Southern Great Plains, and the Northern Great Plains. This production has been possible because many of these varieties have been developed with light insensitive characteristics which permit utilization of photosynthetic energy over a wide area of the earth. The problem of adaptation by varieties is minimized.

During the past 5 years, considerable publicity has been given to these varieties and many of the optimistic producers have contended that the semidwarf varieties would replace substantial quantities of the conventional types. However, it is essential to recognize that the semidwarf wheat varieties display a wide spectrum of physical, chemical, agronomic and disease characteristics. Just like the common conventional wheat varieties, some are better than others. Indeed, in some areas, particularly where irrigation is available or abundant water from natural rainfall has occurred, the semidwarf varieties have appeared quite attractive. However, in terms of total commercial production, they represent only a very small fraction of the total wheat produced. Doubtless, as newer varieties with better agronomic, milling, and baking quality characteristics are developed, the commercial production of the semidwarf types of wheat will rise in the areas where they are adapted.

Hybrid Wheat

Early in the 1960's, the technique of producing hybrid wheat was made practical on a laboratory scale by Dr. Wilson, who was working at Kansas State University. Initial hopes of producing hybrid wheat on a commercial scale within 5 years were expressed. However, the goal has become elusive. In fact, some workers have abandoned hybrid wheat research in favor of other pursuits.

The production of hybrid wheat on a large commercial scale is yet to be accomplished. Doubtless, the most valuable contribution of this work to date has been the creation of new sources of germ plasm for the conventional breeding program. However, a survey of production trends would be incomplete without recognition of this development and appreciation of the fact that considerable work must yet be accomplished before large scale production of hybrid wheat becomes commercially feasible.

Feed Wheat

It seems to me that the new farm program, in conjunction with the climatic conditions which have produced abundant crops, has emphasized the classical tendency for high wheat yields to be accompanied by low wheat prices. Under these circumstances, wheats tending to produce the higher yield appear more attractive in the short term economic standpoint than wheats having the lower yield tendency but potentially greater quality characteristics.

One of the results of this tendency has been to rekindle interest in the use of wheat as feed for livestock. It is anticipated that for the year ending June 30, 1971, the use of wheat as feed may reach the level of 235 million bushels or approximately 3.4 times the U.S. usage in the 1967-68 crop year. If so, it would rival the record levels of 25 years ago when, during World War II, wheat was moved into these channels with the help of a government subsidy. The main reason for the revival of wheat feeding is, of course, the price relationships among wheat, corn, and coarse grains that have developed in recent months.

Many of the wheat growers who have associated livestock interests have tended not to alter the image of wheat as a potential food product; they have continued to regard it mainly as a cash crop, even when its price is at potential feed levels. I would anticipate that more farmers would reevaluate this position in future years.

World Production Trends

Up to this time, we have been talking about the trends of grain production in the United States, which is one of the six major wheat export nations in the world. While statistics obviously are not completed for the crop year 1971, perhaps by scanning the statistics for recent years, one may put the significance of the six major crop reporting nations in some degree of perspective.

During the 5 years from 1954 to 1959, the average annual world wheat production, excluding that of China, was about 7.2 billion bushels. Production progressively increased reaching a maximum of 11.2 billion in the crop year 1968-69. In the most recent year for which reports are available, 1970-71, (World Wheat Statistics published by the International Wheat Council) approximately 10.4 billion bushels of wheat were produced in the world, exclusive of China. Of this amount, the six major exporters of the world produced 58.8 percent; and Russia, the major wheat producer in the world, produced 34 percent. If one were to place countries in order of wheat production, the top six would be Russia 34 percent, the United States 13 percent, France 4.6 percent, Canada 3 percent, Australia 2.7 percent, and Argentina 1.5 percent.

By comparison, production statistics of the 1959-64 period are, respectively, 25 percent for Russia, 14.7 percent for USA, 6.3 percent for Canada, 5.1 percent for France, 3.3 percent for Australia, and 2.7 percent for Argentina. Apparently, in this 10-year span, Russia has increased its percentage of the total wheat production of the world by 5 percentage points, and these percentage points have come roughly from a 2 percentage point reduction by the United States, 1 percentage point reduction by France, 1 percentage point reduction by Argentina, and 2 percentage points reduction by Canada.

Canada

Canada's 1971 wheat crop has shown a remarkable 57 percent increase in production over that of the 1970 crop. The 1971 crop is estimated to be about 523 million bushels. While this is 14 percent below the 10-year average of approximately 610 million bushels, it would once again move the Canadian production into approximately 6 percent of the world total. The fluctuation in Canadian production has arisen primarily due to government planning. Because the Canadian government plays a key role in establishing the policies governing Canadian wheat production and domestic and export marketing, the Canadian type of wheat production has shown less tendency to be influenced by new and popular types of promotional movements.

The Western Prairie Provinces are the primary producers of Canadian spring wheat for export. Because of the Canadian licensing laws which impose certain restrictions on seed sales and utilization in Canada, the Canadian production has been limited primarily to the conventional type of common and durum wheats. The tendency towards the promotion of semidwarfs in commercial production has not occurred in Canada because these varieties are not licensed, the major exception being the variety Pitic 62 which has been licensed as a feed wheat in western Canada.

In general, bread-type wheats are largely of a type produced by the Canadian breeding team which has historically used Marquis as a quality and seed type for reference purposes. Contrariwise, the Canadians have employed Mindum, a variety produced by the University of Minnesota, as the standard of quality for their durums. They have recently released their first three durum wheats in their breeding program and are switching their standard of quality to one of the Canadian released types.

To place Canadian wheat in a more competitive position, changes in the Canadian marketing system have been evident during the last few years. One of the most recent innovations is the inclusion of protein content in the grading system for Canadian western red spring wheat. Another, is the creation of three new grading classifications, C.W. red spring, utility, and fair average quality.

France

During the past 10 years, the total wheat production of France has represented about 4 to 5 percent of the total wheat production and slightly less than half of the wheat production of Europe. This trading season, the increase in domestic wheat supplies in Europe will be a depressing factor on the world wheat trade. It is anticipated that the decline in wheat imports by European countries will perhaps be less than the increase in wheat production. According to foreign agricultural reports, there are several reasons for these tendencies. First, the stocks in the countries of the European Economic Community are unusually low and some of the 1971 wheat crop will likely go toward an increase in carry-over.

Second, the quality of the wheat crop in 1971 in Europe is probably not equal to the relatively good quality which was enjoyed in 1970. This could mean an increased need for imported premium wheats.

Third, there appear to be large amounts of wheat in the EEC which may be diverted to feed use. If the EEC emphasizes denaturing subsidies, this could result in a greater need for imported quality wheat for food purposes.

It has been reported that the quality of this year's soft wheat crop is lower in test weight but higher in protein; as a result, the milling quality is probably poorer than in past years. In addition, reports of the presence of ergot in wheat have been made for the areas south and southeast of Paris.

Probably the factor of considerable concern to certain wheat producers in the United States is the remarkable increase in production of durum wheat in France. In 1966, the French produced about 2.4 million bushels of durum. Production increased to 16.5 million in 1970; and a goal of approximately 25 million bushels is set for 1975.

While the yield of durum wheat in the Paris Basin has increased, the curious point is that the varieties which the French grow are the varieties, Lakota and Wells, which were produced by the wheat breeding team at Fargo, North Dakota. This is another clear indication of the degree of interdependence of wheat production and utilization in the international theater.

One of the objectives of the French durum project is to make the EEC self-sufficient with respect to durum. This is possible primarily because the EEC has a sufficiently attractive durum premium which compensates the farmer for the lower yield of the durum compared to the common wheat types. However, it is reported that for the 1971 crop, a considerable amount of the durum does not meet the minimum of 76 kilograms per hectoliter to qualify for the EEC premium; doubtless, this is due to the rainy weather which occurred in Europe this year and which resulted in an abnormally large amount of chalky, yellow kernels and damage. If sufficient quantities of durum are found not eligible for the intervention premium and are not purchased by the semolina manufacturers, then this, as yet, undetermined amount doubtless would be used as animal feed.

If these reports are correct, it is quite probable that France will need to import more of the strong types of durum this year than last. These imported durums would be blended with the domestic durum to offset the relatively poor quality. As a result, the French demand for U.S. Amber Durum should be greater than originally forecast.

Australia

The trends in Australia likewise have shown recognition of increased world competition. Historically, Australia has produced white wheat and has traded on the basis of fair average quality. Wheat quality was related primarily to the region and port from which the grain originated. In recent years, changes in the grading system have been initiated. These provide four primary types of wheat quality, high protein prime hards, an average quality type, low protein types, and damaged wheats. While this statement is an oversimplification of the system, it is indicative of the fact that Australians have recognized the need to trade on some basis other than merely fair average quality.

One must recognize that Australian production is highly dependent upon available moisture. In the northern New South Wales and Queensland areas, the high protein types of wheat are able to be produced when sufficient rainfall occurs. It is in this region, also, that Australia has initiated production of some durum types.

It must be recognized that Australia, being in the Southern Hemisphere, produces the white wheat which is a spring type; it is sown in the fall, permitted to grow over winter and harvested early in the spring prior to the time that the temperatures are elevated; thus, they produce a spring, white wheat grown under a winter type habit. When conditions are favorable in northeastern New South Wales, a relatively strong, relatively high protein type of bread wheat is produced. In the southeast Province of Victoria, the wheats are of lower protein content, primarily because of the greater abundance of water.

The Australians control their wheat, seeds, and marketing by government action in a manner somewhat similar to that displayed by Canada; however, there is considerably less national control in Australia. But, the Commonwealth is capable of exerting its influence to adjust total wheat stocks as the occasion may arise.

Based on preliminary wheat planting intentions, the Foreign Agricultural Service estimates that about 18 million acres will be planted in

1971-72 with a subsequent harvest of about 10 million metric tons, roughly 370 million bushels. This is well below the 544 million bushels harvested in the 1968-69 crop year.

Soviet Union

As previously indicated, a major factor in wheat production in the world is the Soviet Union which accounts for 30-34 percent of the total wheat production. According to available sources, the grain harvest for the 1971 crop will not be as good as last year. The total wheat acreage is approximately 1 million hectares below last year. There were approximately 46 million hectares of spring wheat planted and 18.5 million hectares of winter wheat. However, Central Asia has been hit by one of the worst droughts in sixty years. Consequently, wheat production is expected to be about 25 percent below last year's record. In contrast, heavy rains have occurred which have delayed the harvest and have increased lodging of the grain. During the past 2 years, it has been reported that the length of the growing season for spring and the timing of the first frost and snowfall have been factors resulting in losses in grain production.

Problems of sporadic wheat harvests have caused the Russians to recently purchase substantial quantities of seed of new HRS types from the United States.

Summary

In summary, it is anticipated that world trade in wheat may increase this year but the competition promises to remain intense among the principal exporters of the world, Russia, United States, France, Canada, Australia, and Argentina. While wheat supplies are abundant in certain areas of the world, weather and quality problems in other areas will afford opportunities for enhancement for world trade among the exporting and importing nations.

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SENATOR FRANK CARLSON FORUM ON WORLD FOOD PROBLEMS [1]

By Glenn S. Beck, Kansas State University

The Carlson Forum brought together leaders from U.S. Agency for International Development, USDA, Land-Grant Universities, Grain Industry, Trade Associations, and Farm Organizations to discuss the subject "Gearing World Grain and Grain Product Marketing to the Needs of the 1970's." Deliberations of the Forum are presented here in summary form. The Forum concluded its 3-day session by passing a resolution calling for the continuation of foreign aid by the U.S. Congress and adopting seven recommendations relative to foreign aid and grain marketing activities.

Resolution

1. Foreign assistance serves vital United States national interests and the cause of world peace.

2. Terminating foreign assistance at this critical point in world affairs would jeopardize the accomplishments of 25 years and pose a grave threat to world peace.

3. We, therefore, urge the Congress of the United States to take all necessary steps to continue a comprehensive foreign assistance program. The recent action of the United States Senate affords the opportunity to change the program so it will better serve the needs of the 1970's.

Recommendations

1. USAID is to be commended for the new directions it is taking, particularly the increased emphasis on research and the multi-national approach.

   As new legislation is drafted, the Carlson Forum recommends that military aid be separated from technical assistance and that the new thrust emphasize contractual technical assistance programs in agricultural production and marketing.

2. The Land-Grant Universities represent the largest single pool of scientific and technical personnel whose training and experience qualify them for carrying out programs of training and technical assistance directed toward the solution of the world's food problems. As the new foreign aid program develops, it is recommended that the association between AID and the Land-Grant Universities in these programs be continued and strengthened.

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[1] Sponsored by Kansas State University, Manhattan, Kans., November 1-3, 1971.

3. The Food for Peace Act (PL-480) as amended in 1966, besides serving a humanitarian interest, has built new markets for U.S. agricultural products and has served the security and foreign policy interests of the United States.

   It is recommended that this be continued in its present form.

4. The Carlson Forum supports the involvement of USAID in the World Consultative Group and endorses the list of high priority research items established by that group as follows:

   1. Food legumes
   2. Upland crops, including corn, sorghum, millet
   3. Livestock production in Africa
   4. Soil and water
   5. Farm management

   In addition it is recommended that high priority also be given to studies related to marketing, processing, and distribution of foods.

5. Producer groups in the United States are commended for taxing themselves to provide funds to promote, educate, sponsor research, and otherwise develop grain trade.

   It is recommended that these activities be continued.

6. The Forum recommends a congressional investigation into labor disputes that are disrupting the handling and transporting of grains so that procedures may be developed to resolve these disputes quickly and fairly in the public interests.

7. It is recommended that grades and standards for the evaluation of grain quality be kept under close scrutiny and modified in accordance with world demands.

Summary

1. The Green Revolution resulting from improved production of wheat and rice has provided new hope that the world will be able to feed itself if population growth is brought under control.

2. Research and development efforts directed toward the less developed countries, and concentrated primarily on cereal grains have produced important gains in meeting caloric requirements, but hunger remains as one of the world's leading problems.

3. Malnutrition associated with protein deficiencies has become one of the world's greatest public health problems. Prolonged damage from protein malnutrition is irreversible and seriously limits the productive capacity of millions of people.

4. Cereal grains making up about 85 percent of the diet among people in the less developed countries are generally deficient in protein.

5. In a major effort to improve protein nutrition in the LDC's, the USAID is sponsoring research to fortify food grains with either synthetic amino acids or with other natural forms of protein. In addition, plant breeding research is being directed toward improving the protein quality of cereal grains (such as high lysine corn) and to increase food legume production.

6. The decade of the 1970's will be one of readjustment in world grain trade resulting from technological developments such as improved high yielding cereal grains and the fortification of cereal based foods.

7. Increased grain production in the LDC's has created changes in the worldwide storage, distribution, and marketing systems, thereby creating problems that demand early attention.

8. Increased worldwide production of grain and livestock feed ingredients has caused a decline in the rate of growth of world cereal trade.

9. Worldwide grain production may be expected to increase during the 1970's. Unless there is worldwide cooperation in establishing effective measures of production control along with increased utilization of grains as human food, as livestock feed, and in industrial uses, there could be a serious problem that supplies will exceed effective demand by 1980.

10. Low per capita income in the LDC's is the greatest single constraint to increased demand, particularly of the higher protein foods, hence problems of malnutrition will continue despite increased production.

11. Another major constraint on increased demand for higher protein foods, including food legumes and animal products, is the lack of education among consumers in the LDC's concerning nutritional requirements.

12. The world market for grain from the United States may be divided into three parts - the developed noncommunist countries, the LDC's, and the Communist countries.

    (a) Present markets in the developed countries are encountering increasing uncertainties resulting from protectionism, high price supports, such as in the EEC, and increased competition from other grain producing countries.

    (b) If PL-480 is continued, the market in the LDC's could stabilize. Although the Green Revolution has produced remarkable improvements in these countries, the lack of birth control will lead to increased needs.

    (c) The Communist countries offer a potentially expanding market for some grains, but could become competitors in grains such as rice (China) and wheat (Russia).

13. The ability of the United States to compete in world markets will depend on the ability to consistently identify and deliver high quality grains as needed at competitive prices. There is a need to continuously evaluate our grades and standards in the light of changing world demand.

14. The interruption of export flows of grain brought about by labor disputes are seriously jeopardizing the ability of the United States to maintain a consistently reliable supply of grain for export at competitive prices.

15. Unless U.S. carriers can offer competitive ocean freight rates for transportation of grains, the competitive position of the United States in world grain trade will be adversely affected by restrictions of movements to U.S. carriers.

16. A major portion of the handling and transportation costs of grain from the U.S. producer to an overseas port are domestic; therefore, it is very important to improve the efficiency of grain transportation systems within the United States.

PLANNED ACTIVITIES OF THE NATIONAL WHEAT INSTITUTE

By E. L. Hatcher, National Wheat Institute

The National Wheat Institute was recently founded because of wheat producer interest in a self-help program of research and promotion. Because of the newness of the Institute, I would like to review with you the development of the Institute before discussing the planned activities.

During 1968 world wheat prices were higher than U.S. domestic prices, and during that period an inverse subsidy fund was accumulated. Funds accumulated in the pool totaled $4,206,569. Based on the distribution of 1968 domestic wheat certificate payments, 832,000 wheat producers were eligible to share in the pool, amounting to a payment of $5.00 to each producer, when distributed to eligible producers on a pro rata basis.

Recognizing the greater potential for industrywide benefits if the fund remained intact for wheat research and promotion, wheat producers prevailed upon Congress for legislative authority.

During hearings before the Subcommittee on Livestock and Grains of the Committee on Agriculture, House of Representatives, testimony developed indicating that producers would voluntarily contribute $2 million of the $4.2 million for research and promotion. This statement underlines the full understanding of those supporting the legislation and producer's interest in a self-help program as $2,043,000 was the total of the funds contributed by producers.

The Wheat Research and Promotion Act was introduced in the House of Representatives on August 13, 1969, and referred to the Committee on Agriculture. It was favorably reported back to the House and passed on September 14, 1970.

The Senate put its approval on the bill on September 21, 1970, and the bill was subsequently signed into law by President Nixon on September 26. The new law provided the opportunity for producers to retain their individual share of the pool or to voluntarily leave their share in the pool for a joint research and promotion effort to increase the utilization of wheat and to carry out a program of research and promotion.

Representatives of the National Grange, Farmers Union, National Farmers Organization, and the National Association of Wheat Growers formed a Producers Informational Committee to publicize producer options. The above organizations and the Durum Growers Association organized to create an organization to qualify under the law to administer the new program. Later the National Federation of Grain Cooperatives and Midcontinent Farmers Association joined the effort.

The National Wheat Institute, a nonprofit organization, was incorporated in the District of Columbia, on October 8, 1970. It set as its goals: (1) Expansion of domestic and foreign markets; (2) increased utilization of U.S. wheat; and (3) creation of other programs deemed to benefit wheat producers in the United States. All activities would be conducted under an agreement with the U.S. Department of Agriculture by authority of the Wheat Research and Promotion Act.

Careful consideration was given to represent all U.S. wheat producers. General farm organizations and national wheat organizations were invited to help create the National Wheat Institute. The board was established to represent these organizations and other qualifying organizations, the various classes of wheat and production areas.

An agreement with the Department of Agriculture was signed on July 28, 1971.

NWI's legislative history establishes general guideline for the Institute in selecting projects to carry out research and promotion. The Secretary of Agriculture is authorized to approve a program of research and promotion designed to expand domestic and foreign markets and increase utilization for U.S. wheat. Specific mention is made to the need to reverse the downward trend of flour consumption, prospects for wheat utilization in industrial channels, market testing or promotion, the need in some cases for additional research on marketing of byproducts, and human nutrition research. Other areas of need were also mentioned including promotional efforts, such as the "Day of Bread," and public relations efforts on behalf of all of agriculture.

In interpretation of congressional intent the area of production research is prohibited and the value of extending a large portion of the funds in the area of straight public relations in a "one-shot" program is questioned.

Recently, the board voted to undertake a 6-month study to determine which areas of research and promotion for developing new uses and markets for wheat will be "most promising" for funding. Status of existing efforts with public or private funding will be analyzed.

The study has the short-range objective of assisting board members to select projects with the greatest potential and the long-range objective of assisting all groups carrying out wheat related research and promotion.

Already 120 projects totaling over $12 million, six times the funds available, have been submitted to the board. They have come from universities, private firms, groups interested in product marketing, State wheat associations,and commissions.

The NWI board has submitted a "plan of operation" to the Department of Agriculture which includes the "State of the Art" study and projection as I outlined earlier. Under our agreement, the Department has until early December to approve or disapprove our plan as submitted.

When funds become available, the study will begin. The board will immediately begin to screen other proposals and hopefully a few of these will be of sufficient merit so we can launch the initial stages of our program during the 6-month period of the "State of the Art" review.

We are still accepting proposals for consideration and will until all funds are committed. If you have a research or promotion project that you feel would be of real assistance to us in expanding wheat usage, we are interested.

We would like proposals submitted in brief form outlining (1) who is submitting the proposal and qualifying background; (2) what is the project; (3) where will it be carried out; and what will be the duration of time; and (4) what is the approximate cost. We would like 12 copies of each proposal.

In conclusion, I would like to thank those responsible for planning this conference. It has been very informative and of great help to myself and to other members of the Institute in attendance. I would also like to thank all of you who have taken time to personally discuss the projects and the role of the new Institute. Your guidance based on research experience will be most helpful in the decision-making period ahead.

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